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TRANSACTIONS
OF THE
AMERICAN PHILOSOPHICAL SOCIETY.

ARTICLE I.

A NEW METHOD OF DETERMINING THE GENERAL PERTURBATIONS OF
THE MINOR PLANETS.

BY WILLIAM McKNIGHT RITTER, M.A.

Read before the American Philosophical Society, February 28, 1896.

PREFACE.

In determining the general perturbations of the minor planets the principal difficulty arises from the large eccentricities and inclinations of these bodies. Methods that are applicable to the major planets fail when applied to the minor planets on account of want of convergence of the series. For a long time astronomers had to be content with finding what are called the special perturbations of these bodies. And it was not until the brilliant researches of HANSEN on this subject that serious hopes were entertained of being able to find also the general perturbations of the minor planets. HANSEN'S mode of treatment differs entirely from those that had been previously employed. Instead of determining the perturbations of the rectangular or polar coördinates, or determining the variations of the elements of the orbit, he regards these elements as constant and finds what may be termed the perturbation of the time. The publication of his work, in which this new mode of treatment is given, entitled *Auseinandersetzung einer zweckmässigen Methode zur Berechnung der absoluten*

Störungen der kleinen Planeten, undoubtedly marks a great advance in the determination of the general perturbations of the heavenly bodies.

The value of the work is greatly enhanced by an application of the method to a numerical example in which are given the perturbations of Egeria produced by the action of Jupiter, Mars, and Saturn. And yet, notwithstanding the many exceptional features of the work commending it to attention, astronomers seem to have been deterred by the refined analysis and laborious computations from anything like a general use of the method; and they still adhere to the method of special perturbations developed by LAGRANGE. HANSEN himself seems to have felt the force of the objections to his method, since in a posthumous memoir published in 1875, entitled *Ueber die Störungen der grossen Planeten, insbesondere des Jupiters*, his former positive views relative to the convergence of series, and the proper angles to be used in the arguments, are greatly modified.

HILL, in his work, *A New Theory of Jupiter and Saturn*, forming Vol. IV of the *Astronomical Papers of the American Ephemeris*, has employed HANSEN'S method in a modified form. In this work the author has given formulæ and developments of great utility when applied to calculations relating to the minor planets, and free use has been made of them in the present treatise. With respect to modifications in HANSEN'S original method made by that author himself, by HILL and others, it is to be noted that they have been made mainly, if not entirely, with reference to their employment in finding the general perturbations of the major planets.

The first use made of the method here given was for the purpose of comparing the values of the reciprocal of the distance and its odd powers as determined by the process of this paper, with the same quantities as derived according to HANSEN'S method. Upon comparison of the results it was found that the agreement was practically complete. To illustrate the application of his formulæ, HANSEN used Egeria whose eccentricity is comparatively small, being about $\frac{1}{12}$. The planet first chosen to test the method of this paper has an eccentricity of nearly $\frac{1}{7}$. And although the eccentricity in the latter planet was considerably larger, the convergence of the series in both methods was practically the same. It was then decided to test the adaptability of the method to the remaining steps of the problem, and the result of the work has been the preparation of the present paper.

HANSEN first expresses the odd powers of the reciprocal of the distance between the planets in series in which the angles employed are both eccentric anomalies. He then transforms the series into others in which one of the angles is the mean anomaly of the disturbing body. He makes still another transformation of his series so as to be able to integrate them.

In the method of this paper we at first employ the mean anomaly of the disturbed and the eccentric anomaly of the disturbing body, and as soon as we have the expressions for the odd powers of the reciprocal of the distance between the bodies, we make one transformation so as to have the mean anomalies of both planets in the arguments. These angles are retained unchanged throughout the subsequent work, enabling us to perform integration at any stage of the work.

In the expressions for the odd powers of the reciprocal of the distance we have, in the present method, the La Place coefficients entering as factors in the coefficients of the various arguments. These coefficients have been tabulated by RUNKLE in a work published by the SMITHSONIAN INSTITUTION entitled *New Tables for Determining the Values of the Coefficients in the Perturbative Function of Planetary Motion*; and hence the work relating to the determination of the expressions for the odd powers of the reciprocal of the distance is rendered comparatively short and simple.

In the expression for Δ^2 , the square of the distance, the true anomaly is involved. In the analysis we use the equivalent functions of the eccentric anomaly for those of the true anomaly, and when making the numerical computations we cause the eccentric anomaly of the disturbed body to disappear. This is accomplished by dividing the circumference into a certain number of equal parts relative to the mean anomaly and employing for the eccentric anomaly its numerical values corresponding to the various values of the mean anomaly.

Having the expressions for the odd powers of the reciprocal of the distance in series in which the angles are the mean anomaly of the disturbed body and the eccentric anomaly of the disturbing body, we derive, in Chapter II, expressions for the J or Besselian functions needed in transforming the series found into others in which both the angles will be mean anomalies.

In Chapter III expressions for the determination of the perturbing function and the perturbing forces are given. Instead of using the force involving the true anomaly we employ the one involving the mean anomaly. The disturbing forces employed are those in the direction of the disturbed radius-vector, in the direction perpendicular to this radius-vector, and in the direction perpendicular to the plane of the orbit.

Having the forces we then find the function W by integrating the expression

$$\frac{dW}{n \cdot dt} = A \cdot a \frac{d\Omega}{d\bar{g}} + B \cdot ar \cdot \frac{d\Omega}{dr},$$

in which A , and B are factors easily determined.

From the value of W we derive that of \bar{W} by simple mechanical processes, and then the perturbations of the mean anomaly and of the radius-vector are found from

$$n \cdot \delta z = n \int \bar{W} \cdot dt$$

$$v = -\frac{1}{2}n \int \frac{d\bar{W}}{d\gamma} \cdot dt,$$

γ being a particular form for g .

The perturbation of the latitude is given by integrating the equation

$$\frac{d \cdot \frac{u}{\cos i}}{n \cdot dt} = C \cdot a^2 \frac{d\Omega}{dZ},$$

C being a factor found in the same manner that A and B were.

It will be noticed that in finding the value of $n \cdot \delta z$ two integrations are needed; in finding the perturbation of the latitude only one is required.

The arbitrary constants introduced by these integrations are so determined that the perturbations become zero for the epoch of the elements.

In all the applications of the method of this paper to different planets the circumference has been divided into sixteen parts, and the convergence of the different series is all that can be desired. In computing the perturbations of those of the minor planets whose eccentricities and inclinations are quite large, it may be necessary to divide the circumference into a larger number of parts. In exceptional cases, such as for Pallas, it may be necessary to divide the circumference into thirty-two parts.

In the different chapters of this paper the writer has given all that he conceives necessary for a full understanding of all the processes as they are in turn applied. And he thinks there is nothing in the method here presented to deter any one with fair mathematical equipment from obtaining a clear idea of the means by which astronomers have been enabled to attain to their present knowledge of the motions of the heavenly bodies. The object always kept in mind has been to have at hand, in convenient form for reference and for application, the whole subject as it has been treated by HANSEN and others. Thus in connection with HANSEN'S derivation of the function W , to obtain clearer conceptions of some matters presented, the method of BRÜNNOW for obtaining the same function has also been given. In some stages of the work where the experience of the writer has shown the need of particular care the work is

given with some detail. And while the writer is fully aware that here he may have exposed himself to criticism, it will suffice to state that he has not had in mind those competent of doing better, but rather the large class of persons that seems to have been deterred thus far, by imposing and formidable-looking formulæ, from becoming acquainted with the means and methods of theoretical astronomy. In the present state of the science there is greatly needed a large body of computers and investigators, so as to secure a fair degree of mastery over the constantly growing material.

The numerical example presented with the theory for the purpose of illustrating the new method will be found to cover a large part of the treatise. The example is designed to make evident the main steps and stages of the work, especially where these are left in any obscurity by the formulæ themselves. As a rule, the formulæ are given immediately in connection with their application and not merely by reference. It has been the wish to make this part of the treatise helpful to all who desire to exercise themselves in this field, and especially to those who desire to equip themselves for performing similar work.

The time required to determine the perturbations of a planet according to the method here given is believed to be very much less than that required by the unmodified method of HANSEN. Nearly all the time consumed in making the transformations by his mode of proceeding is here saved. The coefficients $b^{(i)}$ are much more quickly and readily found by making use of the tables prepared by RUNKLE, giving the values of these quantities. Doubtless experience will suggest still shorter processes than some of those here given and thus bring the subject within narrower limits in respect to the time required. If we compare the time demanded for the computation of the perturbations of the first order, with respect to the mass, produced by Jupiter, with the time needed to correct the elements after a dozen or more oppositions of the planet, computing three theoretical positions for each opposition, it is believed there will not be much difference, if any, in favor of the latter.

Again, when we wish to find only the perturbations of the first order, experience will show where many abridgments may safely be made. And whenever the positions of these bodies are made to depend upon those of comparison stars whose places are often not well determined, it will be found that the quality of the observed data does not justify refinements of calculation.

One of the things most needed in the theory of the motions of the minor planets is a general analytical expression for the perturbing function which may be applicable to all these small bodies. Thus if we had given the value of $a\Omega$ in terms of a periodic series, with literal coefficients and with the mean anomalies of the planets as the argu-

ments, we would at once have $a \frac{d\Omega}{dg}$ by differentiation. And since

$$r \frac{d\Omega}{dr} = a \frac{d\Omega}{da},$$

only two multiplications would be needed in finding the value of $\frac{dW}{n \cdot dt}$, whose expression has been given above.

In the present paper we have dealt only with the perturbations of the first order with respect to the mass. The method has been employed in determining those of the second order also for two of the minor planets; but as those of Althæa, the planet employed in our example, have not yet been found, it was thought best not to give anything on the subject of the perturbations of the second order, until the perturbations of this order, in case of this body, are known.

The writer desires here to record his obligations to Prof. Edgar Frisby, of the U. S. Naval Observatory, Washington, D. C., and to Prof. George C. Comstock, Director of the Washburne Observatory, Madison, Wis., for kindly furnishing him with observations of planets that had not recently been observed; to Mr. Cleveland Keith, Assistant in the office of the American Ephemeris, for most valuable assistance in securing copies of observed places. And to Prof. Monroe B. Snyder, Director of the Central High School Observatory, Philadelphia, he is under special obligations for the interest manifested in the publication of this work, and for continued aid and most valuable suggestions in getting the work through the press.

CHAPTER I.

Development of the Reciprocal of the Distance Between the Planets and its Odd Powers in Periodic Series.

The action of one body on another under the influence of the law of gravitation is measured by the mass divided by the square of the distance. If then Δ be the distance between any two bodies, this distance varying from one instant to another, it will be necessary to find a convenient expression for $\left(\frac{1}{\Delta}\right)^2$ in terms of the time. If r and r' be the radii-vectores of the two bodies, the accented letter always referring to the disturbing body, we have

$$\Delta^2 = r^2 + r'^2 - 2rr' H.$$

If we introduce the semi-major axes a, a' , which are constants, and their relation $\alpha = \frac{a'}{a}$, we obtain

$$\left(\frac{\Delta}{a}\right)^2 = \left(\frac{r}{a}\right)^2 + \left(\frac{r'}{a'}\right)^2 \alpha^2 - 2 \left(\frac{r}{a}\right) \left(\frac{r'}{a'}\right) \alpha H, \quad (1)$$

H being the cosine of the angle formed by the radii-vectores.

Let the origin of angles be taken at the ascending node of the plane of the disturbed, on the plane of the disturbing, body. Let Π, Π' , be the longitudes of the perihelia measured from this point; also let f, f' , be the true anomalies. The angle formed by the radii-vectores is $(f' + \Pi') - (f + \Pi)$; and the angles $f + \Pi, f + \Pi'$, being in different planes, we have

$$H = \cos (f + \Pi) \cos (f' + \Pi') + \cos I \sin (f + \Pi) \sin (f' + \Pi'), \quad (2)$$

I being the mutual inclination of the two planes.

To find the values of Π, Π', I , let Φ be the angular distance from the ascending node of the plane of the disturbed body on the fundamental plane to its ascending

node on the plane of the disturbing body. Let ψ be the angular distance from ascending node of the plane of the disturbing body on the fundamental plane to the same point.

If π, π' , are the longitudes of the perihelia,

ϖ, ϖ' , the longitudes of the ascending nodes on the fundamental plane adopted, which is generally that of the ecliptic, we have

$$\Pi = \pi - \varpi - \Phi, \quad \Pi' = \pi' - \varpi' - \psi. \quad (3)$$

The angles $\Phi, \psi, \varpi - \varpi'$, are the sides of a spherical triangle, lying opposite the angles $i', 180 - i, I$,

i, i' , being the inclination of disturbed and disturbing body on the fundamental plane.

The angles I, Φ, ψ , are found from the equations

$$\left. \begin{aligned} \sin \frac{1}{2} I \sin \frac{1}{2} (\psi + \Phi) &= \sin \frac{1}{2} (\varpi - \varpi') \sin \frac{1}{2} (i + i') \\ \sin \frac{1}{2} I \cos \frac{1}{2} (\psi + \Phi) &= \cos \frac{1}{2} (\varpi - \varpi') \sin \frac{1}{2} (i - i') \\ \cos \frac{1}{2} I \sin \frac{1}{2} (\psi - \Phi) &= \sin \frac{1}{2} (\varpi - \varpi') \cos \frac{1}{2} (i + i') \\ \cos \frac{1}{2} I \cos \frac{1}{2} (\psi - \Phi) &= \cos \frac{1}{2} (\varpi - \varpi') \cos \frac{1}{2} (i - i') \end{aligned} \right\} \quad (4)$$

In using these equations when ϖ is less than ϖ' we must take $\frac{1}{2} (360^\circ + \varpi - \varpi')$ instead of $\frac{1}{2} (\varpi - \varpi')$.

We have a check on the values of I, Φ, ψ , by using the equations given in HANSEN'S posthumous memoir, p. 276.

Thus we have

$$\left. \begin{aligned} \cos p \cdot \sin q &= \sin i' \cdot \cos (\varpi - \varpi') \\ \cos p \cdot \cos q &= \cos i' \\ \cos p \cdot \sin r &= \cos i' \cdot \sin (\varpi - \varpi') \\ \cos p \cdot \cos r &= \cos (\varpi - \varpi') \\ \sin p &= \sin i' \sin (\varpi - \varpi') \\ \sin I \sin \Phi &= \sin p \\ \sin I \cos \Phi &= \cos p \cdot \sin (i - q) \\ \sin I \sin (\psi - r) &= \sin p \cdot \cos (i - q) \\ \sin I \cos (\psi - r) &= \sin (i - q) \\ \cos I &= \cos p \cdot \cos (i - q) \end{aligned} \right\} \quad (5)$$

To develop the expression for $\left(\frac{d}{a}\right)$, we put

$$\left. \begin{aligned} \cos I \cdot \sin \Pi' &= k \sin K, & \sin \Pi' &= k_1 \sin K_1, \\ \cos \Pi' &= k \cos K, & \cos I \cos \Pi' &= k_1 \cos K_1, \end{aligned} \right\} \quad (6)$$

and hence

$$\begin{aligned} H &= \cos f \cdot \cos f' \cdot k \cos (\Pi - K) + \cos f \cdot \sin f' \cdot k_1 \sin (\Pi - K_1) \\ &\quad - \sin f \cdot \cos f' \cdot k \sin (\Pi - K) + \sin f \cdot \sin f' \cdot k_1 \cos (\Pi - K_1). \end{aligned}$$

Introducing the eccentric anomaly ε , we have

$$\cos f = \frac{a}{r} (\cos \varepsilon - e), \quad \sin f = \frac{a}{r} \cdot \cos \phi \cdot \sin \varepsilon,$$

e being the eccentricity, and ϕ the angle of eccentricity; and find

$$\begin{aligned} \frac{r}{a} \cdot \frac{r'}{a'} \cdot H &= \cos \varepsilon \cdot \cos \varepsilon' \cdot k \cos (\Pi - K) - \cos \varepsilon' \cdot ek \cos (\Pi - K) \\ &\quad - \cos \varepsilon \cdot e'k \cos (\Pi - K) + ee'k \cos (\Pi - K) \\ &\quad + \cos \varepsilon \cdot \sin \varepsilon' \cdot \cos \phi' \cdot k_1 \sin (\Pi - K_1) - \sin \varepsilon' \cdot e \cdot \cos \phi' \cdot k_1 \sin (\Pi - K_1) \\ &\quad - \sin \varepsilon \cdot \cos \varepsilon' \cdot \cos \phi \cdot k \sin (\Pi - K) + \sin \varepsilon \cdot e' \cdot \cos \phi \cdot k \sin (\Pi - K) \\ &\quad + \sin \varepsilon \cdot \sin \varepsilon' \cdot \cos \phi \cdot \cos \phi' \cdot k_1 \cos (\Pi - K_1). \end{aligned}$$

Substituting the value of $\frac{r}{a} \cdot \frac{r'}{a'} \cdot H$ in the expression for $\left(\frac{d}{a}\right)^2$ we have

$$\begin{aligned} \left(\frac{d}{a}\right)^2 &= 1 + \alpha^2 - 2e \cdot \cos \varepsilon + e^2 \cos^2 \varepsilon - 2ae'e'k \cos (\Pi - K) \\ &\quad + 2ae'k \cos (\Pi - K) \cos \varepsilon - 2ae' \cos \phi \cdot k \sin (\Pi - K) \sin \varepsilon \\ &\quad - [2\alpha^2 e' - 2ae'k \cos (\Pi - K) + 2ak \cos (\Pi - K) \cos \varepsilon \\ &\quad - 2\alpha \cos \phi \cdot k \sin (\Pi - K) \sin \varepsilon] \cdot \cos \varepsilon' \\ &\quad - [-2ae \cos \phi' \cdot k_1 \sin (\Pi - K_1) + 2\alpha \cos \phi \cos \phi' \cdot k_1 \cos (\Pi - K_1) \sin \varepsilon \\ &\quad + 2\alpha \cos \phi' \cdot k_1 \sin (\Pi - K_1) \cos \varepsilon] \cdot \sin \varepsilon' \\ &\quad + \alpha^2 e'^2 \cdot \cos^2 \varepsilon'. \end{aligned}$$

Putting $\gamma_1, \beta_0, \gamma_2$ for the coefficients of $\cos \varepsilon', \sin \varepsilon', \cos^2 \varepsilon'$, respectively, and γ_0 for the term not affected by $\cos \varepsilon'$ or $\sin \varepsilon'$, we have the abbreviated form

$$\left(\frac{d}{a}\right)^2 = \gamma_0 - \gamma_1 \cdot \cos \varepsilon' - \beta_0 \cdot \sin \varepsilon' + \gamma_2 \cdot \cos^2 \varepsilon'. \quad (7)$$

In this expression for $\left(\frac{J}{a}\right)^2$, γ_0 , γ_1 , and β_0 are functions of the eccentric anomaly of the disturbed body; γ_2 is a constant and of the order of the square of the eccentricity of the disturbing body.

In the method here followed the circumference in case of the disturbed body will be divided into a certain number of equal parts with respect to the mean anomaly, g . The various values of g will then be 0° , $\frac{360^\circ}{n}$, $2.\frac{360^\circ}{n}$, $3.\frac{360^\circ}{n}$, $n-1.\frac{360^\circ}{n}$.

For each numerical value of g , the corresponding value of ε is found from

$$g = \varepsilon - e \sin \varepsilon.$$

Before substituting the numerical values of $\cos \varepsilon$, $\sin \varepsilon$, for the n divisions of the circumference, the expressions for γ_0 , γ_1 , β_0 , will be put in a form most convenient for computation.

Let

$$\left. \begin{aligned} p \sin P &= 2\alpha^2 \frac{e'}{e} - 2\alpha k \cos (\Pi - K) \\ p \cos P &= 2\alpha \cos \phi' k_1 \sin (\Pi - K_1), \end{aligned} \right\} \quad (8)$$

and

$$\left. \begin{aligned} \beta_0 &= f \sin F \\ \gamma_1 &= f \cos F; \end{aligned} \right\} \quad (9)$$

we find

$$\begin{aligned} \beta_0 &= f \sin F = 2\alpha \cos \phi \cos \phi' k_1 \cos (\Pi - K_1) \sin \varepsilon + p \cos P \cos \varepsilon - ep \cos P \\ \gamma_1 &= f \cos F = \left(2\alpha^2 \frac{e'}{e} - p \sin P\right) \cos \varepsilon - 2\alpha \cos \phi k \sin (\Pi - K) \sin \varepsilon + ep \sin P. \end{aligned}$$

And from these equations we find, since

$$\begin{aligned} f \sin (F - P) &= f \sin F \cos P - f \cos F \sin P \\ f \cos (F - P) &= f \cos F \cos P + f \sin F \sin P, \end{aligned}$$

$$\begin{aligned} f \sin (F - P) &= [2\alpha \cos \phi \cos \phi' k_1 \cos (\Pi - K_1) \cos P \\ &\quad + 2\alpha \cos \phi k \sin (\Pi - K) \sin P] \sin \varepsilon + [p - 2\alpha^2 \frac{e'}{e} \sin P] \cos \varepsilon - ep \end{aligned}$$

$$\begin{aligned} f \cos (F - P) &= [2\alpha \cos \phi \cos \phi' k_1 \cos (\Pi - K_1) \sin P \\ &\quad - 2\alpha \cos \phi k \sin (\Pi - K) \cos P] \sin \varepsilon + 2\alpha^2 \frac{e'}{e} \cos P \cos \varepsilon \end{aligned}$$

If we now put

$$\left. \begin{aligned} v \sin V &= 2\alpha \cdot \cos \phi \cdot k \sin (\Pi - K) \\ v \cos V &= 2\alpha \cdot \cos \phi \cdot \cos \phi' \cdot k_1 \cos (\Pi - K_1) \\ w \sin W &= p - 2\alpha^2 \cdot \frac{e'}{e} \cdot \sin P \\ w \cos W &= v \cdot \cos (V - P) \\ w_1 \sin W_1 &= v \cdot \sin (V - P) \\ w_1 \cos W_1 &= 2\alpha^2 \cdot \frac{e'}{e} \cdot \cos P, \end{aligned} \right\} \quad (10)$$

we get

$$\left. \begin{aligned} f \cdot \sin (F - P) &= w \cdot \sin (\varepsilon + W) - ep \\ f \cdot \cos (F - P) &= w_1 \cdot \cos (\varepsilon + W_1). \end{aligned} \right\} \quad (11)$$

Further, if we put

$$R = 1 + \alpha^2 - 2\alpha^2 \cdot e'^2, \quad (12)$$

we have

$$\gamma_0 = R - 2e \cdot \cos \varepsilon + e^2 \cdot \cos^2 \varepsilon + e' \gamma_1$$

$$\text{or,} \quad \gamma_0 = R - 2e \cdot \cos \varepsilon + e^2 \cdot \cos^2 \varepsilon + e' \cdot f \cos F, \quad (13)$$

We find the value of γ_2 from

$$\gamma_2 = \alpha^2 \cdot e'^2.$$

The constants, $k, K, k_1, K_1, p, P, w, W, w_1, W_1, R$, are found, once for all, from the equations given above. For every value of ε we have the corresponding value of f and F from equations (11); hence, also the values of $f \sin F, f \cos F$, which are the values of β_0 and γ_1 . Equation (13) furnishes the value of γ_0 by substituting in it the various numerical values of ε , as was done for β_0 and γ_1 . The value of the coefficient γ_2 being constant, we thus have given the values of $\left(\frac{d}{a}\right)^2$ for as many points along the circumference as there are divisions.

We can put

$$\left(\frac{d}{a}\right)^2 = \gamma_0 - \gamma_1 \cos \varepsilon' - \beta_0 \cdot \sin \varepsilon' + \gamma_2 \cdot \cos^2 \varepsilon'$$

in the form

$$\left(\frac{d}{a}\right)^2 = [C - q \cdot \cos (\varepsilon' - Q)] [1 - q_1 \cdot \cos (\varepsilon' - Q)], \quad (14)$$

in which the factor $1 - q_1 \cdot \cos (\varepsilon' - Q)$ differs little from unity. For this purpose, if we perform the operations indicated in the second expression, and then compare the coefficients of like terms, we find

$$\begin{aligned} \gamma_0 &= C + q \cdot q_1 \sin Q \cdot \sin Q_1 \\ \gamma_1 &= q \cdot \cos Q + q_1 \cdot C \cos Q_1 \\ \gamma_2 &= q \cdot q_1 \cdot \cos (Q + Q_1) \\ \beta_0 &= q \cdot \sin Q + q_1 \cdot C \sin Q_1 \\ 0 &= \sin (Q + Q_1). \end{aligned}$$

The last of these equations is satisfied by putting

$$Q_1 = -Q.$$

The remaining equations then take the form

$$\left. \begin{aligned} \gamma_0 &= C - q \cdot q_1 \cdot \sin^2 Q \\ \gamma_1 &= (q + q_1 \cdot C) \cdot \cos Q \\ \gamma_2 &= q \cdot q_1 \\ \beta_0 &= (q - q_1 \cdot C) \cdot \sin Q \end{aligned} \right\} \quad (15)$$

The expressions

$$\left. \begin{aligned} q \cdot \sin Q &= \beta_0 + \xi \\ q \cdot \cos Q &= \gamma_1 - \eta \\ q_1 \cdot C \cdot \sin Q &= \xi \\ q_1 \cdot C \cdot \cos Q &= \eta \end{aligned} \right\} \quad (16)$$

satisfy the relations expressed by the second and fourth of equations (15), where $C = \gamma_0 + \zeta$.

We have now to find expressions for the small quantities ξ, η, ζ found in these equations.

Equations (16) give

$$q \cdot q_1 \cdot C \sin^2 Q = (\beta_0 + \xi) \cdot \xi.$$

The equation

$$\gamma_0 = C - q \cdot q_1 \sin^2 Q$$

then becomes

$$(\gamma_0 + \zeta) \zeta = (\beta_0 + \xi) \xi \quad (a)$$

From (16) we have, also,

$$q \cdot q_1 \cdot C = (\beta_0 + \xi) \xi + (\gamma_1 - \eta) \eta,$$

from which, since $\gamma_2 = q \cdot q_1$, and $C = \gamma_0 + \zeta$, we obtain

$$(\gamma_0 + \zeta) \cdot \gamma_2 = (\beta_0 + \xi) \xi + (\gamma_1 - \eta) \eta. \quad (b)$$

Equations (16) give again

$$(\gamma_1 - \eta) \xi = (\beta_0 + \xi) \eta. \quad (c)$$

When ζ is known, ξ is found from (a); and the difference between (a) and (b)

$$(\gamma_0 + \zeta) (\gamma_2 - \zeta) = (\gamma_1 - \eta) \cdot \eta \quad (d)$$

gives η when ζ is known.

The equations (a) and (c) give

$$\begin{aligned} \beta_0^2 + 4(\gamma_0 + \zeta) \zeta &= (\beta_0 + 2\xi)^2 \\ \beta_0 + 2\xi &= \gamma_1 \cdot \frac{\xi}{\eta}; \end{aligned}$$

and hence

$$\beta_0^2 + 4(\gamma_0 + \zeta) \zeta = \gamma_1^2 \cdot \frac{\xi^2}{\eta^2}$$

Deduce the values of $\beta_0 + \xi$, $\gamma_1 - \eta$ from (a) and (d), substitute them in (e), we find

$$\frac{\eta^2}{\xi^2} = \frac{\gamma_2}{\zeta} \cdot \frac{\gamma_0}{\gamma_1}.$$

The last equation then takes the form

$$0 = \gamma_1^2 \cdot \zeta - \beta_0^2 (\gamma_2 - \zeta) - 4 (\gamma_0 + \zeta) (\gamma_2 - \zeta) \cdot \zeta. \quad (e)$$

This equation furnishes the value of ζ ; and with ζ known, we find ξ , η , from equations already given. The three equations giving the values of the quantities sought are

$$\left. \begin{aligned} \zeta^3 + (\gamma_0 - \gamma_2) \zeta^2 + \frac{1}{4} (\gamma_1^2 + \beta_0^2 - 4 \gamma_0 \cdot \gamma_2) \zeta - \frac{1}{4} \cdot \beta_0^2 \cdot \gamma_2 &= 0 \\ \xi^2 + \beta_0 \cdot \xi - (\gamma_0 + \zeta) \zeta &= 0 \\ \eta^2 - \gamma_1 \cdot \eta + (\gamma_0 + \zeta) (\gamma_2 - \zeta) &= 0 \end{aligned} \right\} \quad (f)$$

Finding the values of ζ , ξ , η , from these equations, and arranging with respect to γ_2 , preserving only the first power, we have

$$\left. \begin{aligned} \zeta &= \frac{\beta_0^2}{\gamma_1^2 + \beta_0^2} \cdot \gamma_2 \\ \xi &= \frac{\gamma_0 \cdot \beta_0}{\gamma_1^2 + \beta_0^2} \cdot \gamma_2 \\ \eta &= \frac{\gamma_0 \cdot \gamma_1}{\gamma_1^2 + \beta_0^2} \cdot \gamma_2 \end{aligned} \right\} \quad (g)$$

Substituting these values in equations (16), they become

$$\left. \begin{aligned} q \cdot \sin Q &= \beta_0 + \frac{\gamma_0 \cdot \beta_0}{\gamma_1^2 + \beta_0^2} \cdot \gamma_2 \\ q \cdot \cos Q &= \gamma_1 - \frac{\gamma_0 \cdot \gamma_1}{\gamma_1^2 + \beta_0^2} \cdot \gamma_2 \\ q_1 C \sin Q &= \frac{\gamma_0 \cdot \beta_0}{\gamma_1^2 + \beta_0^2} \cdot \gamma_2 \\ q_1 C \cos Q &= \frac{\gamma_0 \cdot \gamma_1}{\gamma_1^2 + \beta_0^2} \cdot \gamma_2 \end{aligned} \right\} \quad (17)$$

noting that $C = \gamma_0 + \zeta$.

If more accurate values of ζ , ξ , η , are needed than those given by equations (g), we proceed as follows:

Substitute the value of ζ given by (g) in the second term of the first of equations (f), we find, up to terms including γ_2^2 ,

$$\zeta = \frac{\beta_0^2}{\gamma_1^2 + \beta_0^2} \cdot \gamma_2 + 4 \cdot \frac{\gamma_0 \cdot \beta_0^2}{(\gamma_1^2 + \beta_0^2)^2} \cdot \gamma_2^2 - 4 \cdot \frac{\gamma_0 \cdot \beta_0^4}{(\gamma_1^2 + \beta_0^2)^3} \cdot \gamma_2^2. \quad (18)$$

The last two of (f) give also

$$\begin{aligned}\xi &= \frac{C \cdot \zeta}{\beta_0} - \frac{C^2 \cdot \zeta^2}{\beta_0^3} \\ \eta &= \frac{C(\gamma_2 - \zeta)}{\gamma_1} + \frac{C^2(\gamma_2 - \zeta)^2}{\gamma_1^3}.\end{aligned}$$

Introducing the values of f , F , given by (11), putting

$$\begin{aligned}\chi &= \gamma_2 + 4 \cdot \gamma_2^2 \cdot \frac{\gamma_0}{f^2} \cdot \cos^2 F \\ \chi' &= \gamma_2 - 4 \cdot \gamma_2^2 \cdot \frac{\gamma_0}{f^2} \cdot \sin^2 F\end{aligned}\tag{19}$$

we have

$$\zeta = \chi \cdot \sin^2 F,$$

so that

$$C = \gamma_0 + \chi \cdot \sin^2 F.\tag{20}$$

Moreover, since

$$\gamma_2 - \zeta = \chi' \cdot \cos^2 F,$$

we find from the expressions for ξ , η , given above,

$$\begin{aligned}\beta_0 + \xi &= f \cdot \xi' \cdot \sin F, \\ \gamma_1 - \eta &= f \cdot \eta' \cdot \cos F,\end{aligned}$$

if

$$\begin{aligned}\xi' &= 1 + \frac{C\chi}{f^2} - \left(\frac{C\chi}{f^2}\right)^2 \\ \eta' &= 1 - \frac{C\chi'}{f^2} - \left(\frac{C\chi'}{f^2}\right)^2\end{aligned}\tag{21}$$

Substituting these in the expressions for $q \sin Q$, $q \cos Q$, they become

$$\begin{aligned}q \sin Q &= f \cdot \xi' \cdot \sin F \\ q \cos Q &= f \cdot \eta' \cdot \cos F.\end{aligned}\tag{22}$$

The value of q_1 is found from

$$q_1 = \frac{r_2}{q} \quad (23)$$

The quantities q , q_1 , Q can be expressed in another manner. The equations (22) give

$$\begin{aligned} \operatorname{tg} Q &= \frac{\xi'}{\eta'} \cdot \operatorname{tg} F \\ q^2 &= f^2 \cdot \xi'^2 \cdot \sin^2 F + f^2 \cdot \eta'^2 \cdot \cos^2 F; \end{aligned}$$

from which we derive

$$\begin{aligned} Q &= F + \frac{\xi' - \eta'}{\xi' + \eta'} \cdot \sin 2F + \frac{1}{2} \left(\frac{\xi' - \eta'}{\xi' + \eta'} \right)^2 \cdot \sin 4F + \text{etc.} \\ \log. q &= \log. f + \frac{1}{2} \log. (\xi'^2 \cdot \sin^2 F + \eta'^2 \cos^2 F). \end{aligned}$$

Since χ^2 and χ'^2 agree up to terms of the third order, the equations for ξ' and η' give

$$\frac{\xi' - \eta'}{\xi' + \eta'} = \frac{C(\chi + \chi')}{2f^2};$$

or,

$$\frac{\xi' - \eta'}{\xi' + \eta'} = \frac{r_0 r_2}{f^2} + \frac{r_2^2}{2f^2} + \left(2\frac{r_0^2 r_2^2}{f^4} - \frac{r_2^2}{2f^2} \right) \cos 2F$$

Further

$$\xi'^2 \sin^2 F + \eta'^2 \cos^2 F = 1 + 2 \frac{C}{f^2} (\chi \cdot \sin^2 F - \chi' \cos^2 F) - \left(\frac{C\chi}{f^2} \right)^2$$

and

$$\begin{aligned} \frac{1}{2} \log. (\xi'^2 \sin^2 F + \eta'^2 \cos^2 F) &= \frac{C}{f^2} (\chi \sin^2 F - \chi' \cos^2 F) \\ &\quad - \frac{C^2}{f^4} (\chi \sin^2 F - \chi' \cos^2 F)^2 - \frac{1}{2} \left(\frac{C\chi}{f^2} \right)^2 \end{aligned}$$

Substituting the values of χ , χ' , C , given before, we find

$$\begin{aligned} \frac{C}{f^2} (\chi \sin^2 F - \chi' \cos^2 F) &= \frac{r_0^2 r_2^2}{f^4} + \frac{r_2^3}{4f^2} - \left(\frac{r_0 r_2}{f^2} + \frac{r_2^2}{2f^2} \right) \cos 2F \\ &\quad - \left(\frac{r_0^2 r_2^2}{f^4} - \frac{r_2^3}{4f^2} \right) \cos 4F \end{aligned}$$

$$\left(\frac{C\chi}{f^2} \right)^2 = \frac{r_0^2 r_2^2}{f^4}$$

The equation $\gamma_2 = q \cdot q_1$ gives

$$\log. \gamma_2 = \log. q + \log. q_1$$

Putting

$$\log. q = \log. f + y,$$

we have for q_1

$$\log. q_1 = \log. \frac{\gamma_2}{f} - y.$$

Writing s for the number of seconds in the radius, and λ_0 for the modulus of the common system of logarithms, we find

$$\left. \begin{aligned} Q &= F + x \\ \log. q &= \log. f + y \\ \log. q_1 &= \log. \frac{\gamma_2}{f} - y \end{aligned} \right\} \quad (24)$$

in which

$$\left. \begin{aligned} x &= s \left(\frac{\gamma_0 \gamma_2}{f^2} + \frac{\gamma_2^2}{2f^2} \right) \sin 2F + s \left(\frac{3\gamma_0^2 \gamma_2^2}{2f^4} - \frac{\gamma_2^2}{4f^2} \right) \sin 4F \\ y &= \lambda_0 \frac{\gamma_2^2}{4f^2} - \lambda_0 \left(\frac{\gamma_0 \gamma_2}{f^2} + \frac{\gamma_2^2}{2f^2} \right) \cos 2F - \lambda_0 \left(\frac{3\gamma_0^2 \gamma_2^2}{2f^4} - \frac{\gamma_2^2}{4f^2} \right) \cos 4F \end{aligned} \right\} \quad (25)$$

And for C we have from the first of (15)

$$C = \gamma_0 + \gamma_2 \cdot \sin^2 Q. \quad (26)$$

By means of the last three equations we are enabled to find the values of Q, q, q_1, C , with the greatest accuracy. The equations (17), where not sufficiently approximate, will, nevertheless, furnish a good check on the values of these quantities. All the quantities in the expression for $\left(\frac{d}{a}\right)^2$ are thus known; and substituting their values corresponding to the various values of g , we have the values of $\left(\frac{d}{a}\right)^2$ for the different points of the circumference.

Using the values of C, q, q_1, Q , just found, HILL, in his *New Theory of Jupiter and Saturn*, has given another expression for $\left(\frac{d}{a}\right)$ which we shall employ.

To transform

$$\left(\frac{d}{a}\right)^2 = (C - q \cdot \cos(\epsilon' - Q)) (1 - q_1 \cdot \cos(\epsilon' + Q))$$

into the required form we put

$$\left. \begin{aligned} \frac{q}{C} &= \sin \chi, & \frac{q_1}{C} &= \sin \chi_1 \\ a &= tg \frac{1}{2} \chi, & b &= tg \frac{1}{2} \chi_1 \\ N &= \frac{\sec \frac{1}{2} \chi \cdot \sec \frac{1}{2} \chi_1}{\sqrt{C}} \end{aligned} \right\} \quad (27)$$

Then

$$\begin{aligned} \left(\frac{d}{a}\right)^2 &= C [1 - \sin \chi \cdot \cos(\epsilon' - Q)] [1 - \sin \chi_1 \cdot \cos(\epsilon' + Q)] \\ &= \frac{C [\sec^2 \frac{1}{2} \chi (1 - \sin \chi \cdot \cos(\epsilon' - Q))]}{\sec^2 \frac{1}{2} \chi} \frac{[\sec^2 \frac{1}{2} \chi_1 (1 - \sin \chi_1 \cdot \cos(\epsilon' + Q))]}{\sec^2 \frac{1}{2} \chi_1} \\ &= \frac{C [1 + tg^2 \frac{1}{2} \chi - 2tg \frac{1}{2} \chi \cos(\epsilon' - Q)]}{\sec^2 \frac{1}{2} \chi} \frac{[1 + tg^2 \frac{1}{2} \chi_1 - 2tg \frac{1}{2} \chi_1 \cos(\epsilon' + Q)]}{\sec^2 \frac{1}{2} \chi_1} \end{aligned}$$

Substituting the values of a, b, N , we get

$$\left(\frac{a}{d}\right)^n = N^n [1 + a^2 - 2a \cos(\epsilon' - Q)]^{-\frac{n}{2}} [1 + b^2 - 2b \cos(\epsilon' + Q)]^{-\frac{n}{2}} \quad (28)$$

We compute the values of a, b, N , corresponding to the different values of g , and check by finding the sums of the odd and the even orders, which should be nearly the same. If we put

$$\begin{aligned} [1 + a^2 - 2a \cos(\epsilon' - Q)]^{-s} &= \left[\frac{1}{2} b^{(0)} + b^{(1)} \cdot \cos \theta + b^{(2)} \cdot \cos 2\theta + b^{(3)} \cdot \cos 3\theta + \text{etc.}\right] \\ [1 + b^2 - 2b \cos(\epsilon' + Q)]^{-s} &= \left[\frac{1}{2} B^{(0)} + B^{(1)} \cdot \cos(\epsilon' + Q) + B^{(2)} \cdot \cos 2(\epsilon' + Q) + \text{etc.}\right] \end{aligned}$$

where $s = \frac{n}{2}$, $\theta = \epsilon' - Q$, we are enabled to make use of coefficients already known.

For $2 \cdot \cos \theta$, write $x + \frac{1}{x}$, and then we have

$$\begin{aligned} \left[1 + a^2 - 2a \cos \theta\right]^{-s} &= \left[1 + a^2 - a \left(x + \frac{1}{x}\right)\right]^{-s} \\ &= \left[1 - ax\right]^{-s} \left[1 - \frac{a}{x}\right]^{-s} \end{aligned}$$

Expanding we have

$$\begin{aligned} \left[1 - ax\right]^{-s} &= 1 + \frac{s}{1} \cdot ax + \frac{s}{1} \cdot \frac{s+1}{2} \cdot a^2 x^2 + \frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+2}{3} \cdot a^3 x^3 + \frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+2}{3} \cdot \frac{s+3}{4} \cdot a^4 x^4 \\ &\quad + \frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+2}{3} \cdot \frac{s+3}{4} \cdot \frac{s+4}{5} \cdot a^5 x^5 + \text{etc.} \\ \left[1 - \frac{a}{x}\right]^{-s} &= 1 + \frac{s}{1} \cdot \frac{a}{x} + \frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{a^2}{x^2} + \frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+2}{3} \cdot \frac{a^3}{x^3} + \frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+2}{3} \cdot \frac{s+3}{4} \cdot \frac{a^4}{x^4} \\ &\quad + \frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+2}{3} \cdot \frac{s+3}{4} \cdot \frac{s+4}{5} \cdot \frac{a^5}{x^5} + \text{etc.} \end{aligned}$$

And hence, for their product, we have

$$\begin{aligned} &1 + \left(\frac{s}{1}\right)^2 \cdot a^2 + \left(\frac{s}{1} \cdot \frac{s+1}{2}\right)^2 \cdot a^4 + \left(\frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+2}{3}\right)^2 \cdot a^6 + \left(\frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+2}{3} \cdot \frac{s+3}{4}\right)^2 \cdot a^8 + \text{etc.} \\ &+ \left[\frac{s}{1} \cdot a + \left(\frac{s}{1}\right)^2 \cdot \frac{s+1}{2} \cdot a^3 + \left(\frac{s}{1} \cdot \frac{s+1}{2}\right)^2 \cdot \frac{s+2}{3} \cdot a^5 \right. \\ &+ \left.\left(\frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+2}{3}\right)^2 \cdot \frac{s+3}{4} \cdot a^7 + \text{etc.}\right] \left(x + \frac{1}{x}\right) \\ &+ \left[\frac{s}{1} \cdot \frac{s+1}{2} \cdot a^2 + \left(\frac{s}{1}\right)^2 \cdot \frac{s+1}{2} \cdot \frac{s+2}{3} \cdot a^4 + \left(\frac{s}{1} \cdot \frac{s+1}{2}\right)^2 \cdot \frac{s+2}{3} \cdot \frac{s+3}{4} \cdot a^6 \right. \\ &+ \left.\left(\frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+2}{3}\right)^2 \cdot \frac{s+3}{4} \cdot \frac{s+4}{5} \cdot a^8 + \text{etc.}\right] \left(x^2 + \frac{1}{x^2}\right) \\ &+ \left[\frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+2}{3} \cdot a^3 + \left(\frac{s}{1}\right)^2 \cdot \frac{s+1}{2} \cdot \frac{s+2}{3} \cdot \frac{s+3}{4} \cdot a^5 \right. \\ &+ \left.\left(\frac{s}{1} \cdot \frac{s+1}{2}\right)^2 \cdot \frac{s+2}{3} \cdot \frac{s+3}{4} \cdot \frac{s+4}{5} \cdot a^7 + \text{etc.}\right] \left(x^3 + \frac{1}{x^3}\right) \\ &+ \text{etc.} \end{aligned}$$

But $x + \frac{1}{x} = 2 \cos \theta$, $x^2 + \frac{1}{x^2} = 2 \cdot \cos 2\theta$, $x^3 + \frac{1}{x^3} = 2 \cdot \cos 3\theta$, etc.,

and hence

$$\begin{aligned}
 \frac{1}{2} b^{(0)} &= 1 + \binom{s}{1}^2 \cdot a^2 + \binom{s}{1} \cdot \frac{s+1}{2} \binom{s+1}{2}^2 \cdot a^4 + \left(\frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+2}{3} \right)^2 \cdot a^6 + \text{etc.} \\
 b^{(1)} &= 2sa \left[1 + \frac{s}{1} \cdot \frac{s+1}{2} \cdot a^2 + \frac{s}{1} \cdot \left(\frac{s+1}{2} \right)^2 \cdot \frac{s+2}{3} \cdot a^4 + \frac{s}{1} \cdot \left(\frac{s+1}{2} \cdot \frac{s+2}{3} \right)^2 \cdot \frac{s+3}{4} \cdot a^6 + \text{etc.} \right] \\
 b^{(2)} &= 2 \cdot \frac{s}{1} \cdot \frac{s+1}{2} \cdot a^2 \left[1 + \frac{s}{1} \cdot \frac{s+2}{3} \cdot a^2 + \frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+2}{3} \cdot \frac{s+3}{4} \cdot a^4 \right. \\
 &\quad \left. + \frac{s}{1} \cdot \frac{s}{2} \cdot \frac{1}{3} \left(\frac{s+2}{3} \right)^2 \cdot \frac{s+3}{4} \cdot \frac{s+4}{5} \cdot a^6 + \text{etc.} \right] \\
 b^{(3)} &= 2 \cdot \frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+2}{3} \cdot a^3 \left[1 + \frac{s}{1} \cdot \frac{s+3}{4} \cdot a^2 + \frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+3}{4} \cdot \frac{s+4}{5} \cdot a^4 \right. \\
 &\quad \left. + \frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+2}{3} \cdot \frac{s+3}{4} \cdot \frac{s+4}{5} \cdot \frac{s+5}{6} \cdot a^6 + \text{etc.} \right]
 \end{aligned} \tag{29}$$

and generally

$$b^{(i)} = 2 \cdot \frac{s}{1} \cdot \frac{s+1}{2} \cdot \dots \cdot \frac{(s+i-1)}{i} \cdot a^i \left[1 + \frac{s}{1} \cdot \frac{s+i}{i+1} \cdot a^2 + \frac{s}{1} \cdot \frac{s+1}{2} \cdot \frac{s+i}{i+1} \cdot \frac{s+i+1}{i+2} \cdot a^4 + \text{etc.} \right]$$

Since $s = \frac{n}{2}$, we find from these expressions the values of the $b^{(i)}$ coefficients for different values of n .

RUNKLE has tabulated the values of $b^{(i)}$ in a paper published by the SMITHSONIAN INSTITUTION. Thus the value of

$$[1 + a^2 - 2a \cos(\epsilon' - Q)]^{-\frac{n}{2}}$$

is obtained with great facility.

The value of $[1 + b^2 - 2b \cos(\epsilon + Q)]^{-\frac{n}{2}}$ is found in the same way.

We now let

$$\begin{aligned}
 c^{(i)} &= \frac{1}{2} \cdot N \cdot B^{(i)} \cdot \cos 2iQ \\
 s^{(i)} &= \frac{1}{2} \cdot N \cdot B^{(i)} \cdot \sin 2iQ
 \end{aligned} \tag{30}$$

And hence have

$$\begin{aligned}
 c^{(0)} &= \frac{1}{2} \cdot N \cdot B^{(0)} \\
 c^{(1)} &= \frac{1}{2} \cdot N \cdot B^{(1)} \cdot \cos 2Q \\
 s^{(1)} &= \frac{1}{2} \cdot N \cdot B^{(1)} \cdot \sin 2Q \\
 c^{(2)} &= \frac{1}{2} \cdot N \cdot B^{(2)} \cdot \cos 4Q \\
 s^{(2)} &= \frac{1}{2} \cdot N \cdot B^{(2)} \cdot \sin 4Q \\
 &\text{etc.} = \text{etc.}
 \end{aligned}$$

Multiplying the series $[\frac{1}{2}b^{(0)} + b^{(1)}.\cos\theta + b^{(2)}.\cos 2\theta + b^{(3)}.\cos 3\theta + \text{etc.}]$
by $[\frac{1}{2}B^{(0)} + B^{(1)}\cos(\epsilon' + Q) + B^{(2)}.\cos 2(\epsilon' + Q) + \text{etc.}]$,

noting that $\theta = Q - \epsilon'$, and arranging the terms with respect to $\cos i\theta$, $\sin i\theta$,
we find

$$\left. \begin{aligned} \left(\frac{a}{d}\right) &= \frac{1}{2}b^{(0)}.c^{(0)} + b^{(1)}.c^{(1)} + b^{(2)}.c^{(2)} \\ &+ [b^{(1)}.c^{(0)} + (b^{(0)} + b^{(2)})c^{(1)} + (b^{(1)} + b^{(3)})c^{(2)}] \cos \theta \\ &+ [\quad + (b^{(0)} - b^{(2)})s^{(1)} + (b^{(1)} - b^{(3)})s^{(2)}] \sin \theta \\ &+ [b^{(2)}.c^{(0)} + (b^{(1)} + b^{(3)})c^{(1)} + (b^{(0)} + b^{(4)})c^{(2)}] \cos 2\theta \\ &+ [\quad + (b^{(1)} - b^{(3)})s^{(1)} + (b^{(0)} - b^{(4)})s^{(2)}] \sin 2\theta \\ &+ [b^{(3)}.c^{(0)} + (b^{(2)} + b^{(4)})c^{(1)} + (b^{(1)} + b^{(5)})c^{(2)}] \cos 3\theta \\ &+ [\quad + (b^{(2)} - b^{(4)})s^{(1)} + (b^{(1)} - b^{(5)})s^{(2)}] \sin 3\theta \\ &+ \quad \quad \quad \text{etc.} \quad \quad \quad \text{etc.} \end{aligned} \right\} \quad (31)$$

Now let

$$\left. \begin{aligned} k_i \cos K_i &= b^{(i)}.c^{(0)} + (b^{(i-1)} + b^{(i+1)})c^{(1)} + (b^{(i-2)} + b^{(i+2)})c^{(2)} \\ k_i \sin K_i &\quad + (b^{(i-1)} - b^{(i+1)})s^{(1)} + (b^{(i-2)} - b^{(i+2)})s^{(2)} \end{aligned} \right\} \quad (32)$$

and we find

$$\begin{aligned} \left(\frac{a}{d}\right) &= k_i [\cos K_i.\cos i\theta + \sin K_i.\sin i\theta] \\ &= k_i \cos(i\theta - K_i) = k_i.\cos(iQ - i\epsilon' - K_i). \end{aligned} \quad (33)$$

Subtracting and adding the angle ig , this becomes

$$\begin{aligned} \left(\frac{a}{d}\right) &= k_i \cos[i(Q - g) - K_i + (ig - i\epsilon')] \\ &= k_i \cos[i(Q - g) - K_i] \cos.i(g - \epsilon') - k_i.\sin[i(Q - g) - K_i] \sin.i(g - \epsilon') \end{aligned} \quad (34)$$

If we put

$$\left. \begin{aligned} A_{i,\kappa}^{(c)} &= \frac{2}{n}k_{i,\kappa} \cos[i(Q_\kappa - g_\kappa) - K_{i,\kappa}] \\ A_{i,\kappa}^{(s)} &= \frac{2}{n}k_{i,\kappa} \sin[i(Q_\kappa - g_\kappa) - K_{i,\kappa}], \end{aligned} \right\} \quad (35)$$

n being the number of divisions, we find

$$\left(\frac{a}{d}\right) = A_{i,\kappa}^{(c)} \cdot \cos i(g_\kappa - \varepsilon'_\kappa) - A_{i,\kappa}^{(s)} \cdot \sin i(g_\kappa - \varepsilon'_\kappa) \quad (36)$$

If now, for the purpose of multiplying the series together, we put

$$\left. \begin{aligned} A_{i,\kappa}^{(c)} &= \Sigma C_{i,\nu}^{(c)} \cdot \cos \nu g + \Sigma C_{i,\nu}^{(s)} \sin \nu g \\ A_{i,\kappa}^{(s)} &= \Sigma S_{i,\nu}^{(c)} \cdot \cos \nu g + \Sigma S_{i,\nu}^{(s)} \sin \nu g \end{aligned} \right\} \quad (37)$$

we have

$$\left(\frac{a}{d}\right) = [\Sigma C_{i,\nu}^{(c)} \cos \nu g + \Sigma C_{i,\nu}^{(s)} \sin \nu g] \cos i(g - \varepsilon') - [\Sigma S_{i,\nu}^{(c)} \cos \nu g + \Sigma S_{i,\nu}^{(s)} \sin \nu g] \sin i(g - \varepsilon') \quad (38)$$

Performing the operations indicated we get

$$\begin{aligned} \Sigma \Sigma \cos(i g - i \varepsilon') \cdot C_{i,\nu}^{(c)} \cos \nu g &= \Sigma \Sigma \frac{1}{2} C_{i,\nu}^{(c)} \cos[(i + \nu) g - i \varepsilon'] + \Sigma \Sigma \frac{1}{2} C_{i,\nu}^{(c)} \cos[(i - \nu) g - i \varepsilon'] \\ \Sigma \Sigma \cos(i g - i \varepsilon') \cdot C_{i,\nu}^{(s)} \sin \nu g &= \Sigma \Sigma \frac{1}{2} C_{i,\nu}^{(s)} \sin[(i + \nu) g - i \varepsilon'] - \Sigma \Sigma \frac{1}{2} C_{i,\nu}^{(s)} \sin[(i - \nu) g - i \varepsilon'] \\ - \Sigma \Sigma \sin(i g - i \varepsilon') \cdot S_{i,\nu}^{(c)} \cos \nu g &= - \Sigma \Sigma \frac{1}{2} S_{i,\nu}^{(c)} \sin[(i + \nu) g - i \varepsilon'] - \Sigma \Sigma \frac{1}{2} S_{i,\nu}^{(c)} \sin[(i - \nu) g - i \varepsilon'] \\ - \Sigma \Sigma \sin(i g - i \varepsilon') \cdot S_{i,\nu}^{(s)} \sin \nu g &= \Sigma \Sigma \frac{1}{2} S_{i,\nu}^{(s)} \cos[(i + \nu) g - i \varepsilon'] - \Sigma \Sigma \frac{1}{2} S_{i,\nu}^{(s)} \cos[(i - \nu) g - i \varepsilon'] \end{aligned}$$

Summing the terms we find

$$\left(\frac{a}{d}\right)^n = \Sigma \Sigma \frac{1}{2} (C_{i,\nu}^{(c)} \mp S_{i,\nu}^{(s)}) \cos[(i \mp \nu) g - i \varepsilon'] \mp \frac{1}{2} \Sigma \Sigma (C_{i,\nu}^{(s)} \pm S_{i,\nu}^{(c)}) \sin[(i \mp \nu) g - i \varepsilon'] \quad (39)$$

From the formula of mechanical quadrature just given, we have $C_{i,0}^{(c)}$, $S_{i,0}^{(c)}$, when $\nu = 0$; but we know that they are $\frac{1}{2} \cdot C_{i,0}^{(c)}$, $\frac{1}{2} S_{i,0}^{(c)}$, as shown by their derivation.

Thus

$$\left. \begin{aligned} A_i^{(c)} &= \frac{1}{2} C_{i,0}^{(c)} + C_{i,1}^{(c)} \cos g + C_{i,2}^{(c)} \cos 2g + \text{etc.} \\ &\quad + C_{i,1}^{(s)} \sin g + C_{i,2}^{(s)} \sin 2g + \text{etc.} \end{aligned} \right\} = \Sigma C_{i,\nu}^{(c)} \cos \nu g + \Sigma C_{i,\nu}^{(s)} \sin \nu g$$

$$\left. \begin{aligned} A_i^{(s)} &= \frac{1}{2} S_{i,0}^{(c)} + S_{i,1}^{(c)} \cos g + S_{i,2}^{(c)} \cos 2g + \text{etc.} \\ &\quad + S_{i,1}^{(s)} \sin g + S_{i,2}^{(s)} \sin 2g + \text{etc.} \end{aligned} \right\} = \Sigma S_{i,\nu}^{(c)} \cos \nu g + \Sigma S_{i,\nu}^{(s)} \sin \nu g.$$

Hence where $\nu = 0$, each series is reduced to its first term.

In the application of the very general formulæ care must be taken to note the signification of the various terms employed.

In case of

$$A_{i,\kappa}^{(c)} = \frac{2}{n} k_{i,\kappa} \cdot \cos [i (Q_\kappa - g_\kappa) - K_{i,\kappa}]$$

$$A_{i,\kappa}^{(s)} = \frac{2}{n} k_{i,\kappa} \cdot \sin [i (Q_\kappa - g_\kappa) - K_{i,\kappa}],$$

n shows the number of divisions of the circumference; and we divide by $\frac{n}{2}$ in forming $k_{i,\kappa}$ to save division when forming the coefficients c_ν, s_ν .

The index and multiple i shows the term in the series

$$\frac{1}{2}b^{(0)} + b^{(1)} \cos (\varepsilon' - Q) + b^{(2)} \cdot \cos 2(\varepsilon' - Q) + b^{(3)} \cdot \cos 3(\varepsilon' - Q) + \text{etc.}$$

The double index i, κ shows the term of the series of La Place's coefficients and the particular point in the circumference.

The index ν shows the general term of the series expressing the values of $A_{i,\kappa}^{(c)}, A_{i,\kappa}^{(s)}$, when we give to ν values from $\nu = 0$, to the highest value of ν needed in the approximation.

In $\frac{2}{n} \cdot k_{i,\kappa}, i(Q_\kappa - g_\kappa) - K_{i,\kappa}$, for each value of i , there are n values of each quantity.

The next step is to express the n values of $A_0^{(c)}, A_1^{(c)}, A_1^{(s)}, A_2^{(c)}, A_2^{(s)}$, etc., respectively in terms of a periodic series. And since these quantities are functions of the mean anomaly g , if we designate them generally by Y , of which the special values are

$$Y_0, \quad Y_1, \quad Y_2, \quad Y_{n-1},$$

we have

$$Y = \left. \begin{aligned} &\frac{1}{2}c_0 + c_1 \cos g + c_2 \cos 2g + \text{etc.} \\ &+ s_1 \sin g + s_2 \sin 2g + \text{etc.} \end{aligned} \right\} \quad (40)$$

The values of c_ν, s_ν , in this series are found from the n special values of Y .

From

$$\begin{aligned} A_1^{(c)}, \text{ or } A_1^{(s)} = & \frac{1}{2} c_0 + c_1 \cos g + c_2 \cos 2g + \text{etc.} \\ & + s_1 \sin g + s_2 \sin 2g + \text{etc.,} \end{aligned}$$

and similarly, for every other value of κ in $A_{i,\kappa}^{(c)}, A_{i,\kappa}^{(s)}$, we have a check on the values of c_ν, s_ν , in each series. Thus if in case of sixteen divisions of the circumference we take $g = 22.^\circ 5$ and find the value of the series, the sum of the terms must equal the value of $A_{i,\kappa}^{(c)}, A_{i,\kappa}^{(s)}$, corresponding to $g = 22.^\circ 5$. And this check should be employed on each series, using that value of g that gives the most values of c_ν and s_ν . If i extends to $i = 9$, we have ten separate checks for the values of $A_{i,\kappa}^{(c)}, A_{i,\kappa}^{(s)}$, respectively.

In the equation

$$\begin{aligned} Y = & \frac{1}{2} c_0 + c_1 \cdot \cos g + c_2 \cdot \cos 2g + c_3 \cdot \cos 3g + \text{etc.} \\ & + s_1 \cdot \sin g + s_2 \cdot \sin 2g + s_3 \cdot \sin 3g + \text{etc.,} \end{aligned}$$

if the circumference is divided into twelve parts, each division is 30° . Then for the special values of Y we have

$$Y_0 = \frac{1}{2} c_0 + c_1 + c_2 + c_3 + \text{etc.}$$

$$\begin{aligned} Y_1 = & \frac{1}{2} c_0 + c_1 \cdot \cos 30^\circ + c_2 \cdot \cos 60^\circ + c_3 \cos 90^\circ + \text{etc.} \\ & + s_1 \sin 30^\circ + s_2 \sin 60^\circ + s_3 \sin 90^\circ + \text{etc.} \end{aligned}$$

$$\begin{aligned} Y_2 = & \frac{1}{2} c_0 + c_1 \cdot \cos 60^\circ + c_2 \cdot \cos 120^\circ + c_3 \cos 180^\circ + \text{etc.} \\ & + s_1 \sin 60^\circ + s_2 \cdot \sin 120^\circ + s_3 \sin 180^\circ + \text{etc.} \end{aligned}$$

$$\begin{array}{cccc} \vdots & \vdots & \vdots & \vdots \end{array}$$

$$\begin{aligned} Y_{11} = & \frac{1}{2} c_0 + c_1 \cdot 330^\circ + c_2 \cdot \cos 300^\circ + c_3 \cos 270^\circ + \text{etc.} \\ & + s_1 \cdot 330^\circ + s_2 \cdot \sin 300^\circ + s_3 \sin 270^\circ + \text{etc.} \end{aligned}$$

In the same way we proceed for any other number of divisions of the circumference.

Now let

$$\begin{array}{ll}
 (0.6) = Y_0 + Y_6 & (\frac{0}{6}) = Y_0 - Y_6 \\
 (1.7) = Y_1 + Y_7 & (\frac{1}{7}) = Y_1 - Y_7 \\
 (2.8) = Y_2 + Y_8 & (\frac{2}{8}) = Y_2 - Y_8 \\
 \vdots & \vdots \\
 (5.11) = Y_5 + Y_{11} & (\frac{5}{11}) = Y_5 - Y_{11}
 \end{array}$$

Then

$$\begin{aligned}
 3(c_0 + 2c_6) &= (0.6) + (2.8) + (4.10) \\
 3(c_0 - 2c_6) &= (1.7) + (3.9) + (5.11) \\
 3(c_2 + c_4) &= (0.6) - [(2.8) + (4.10)] \sin 30^\circ \\
 3(c_2 - c_4) &= [(1.7) + (5.11)] \sin 30^\circ - (3.9) \\
 3(s_2 + s_4) &= [(1.7) - (5.11)] \cos 30^\circ \\
 3(s_2 - s_4) &= [(2.8) - (4.10)] \cos 30^\circ \\
 3(c_1 + c_5) &= (\frac{0}{6}) + [(\frac{2}{8}) - (\frac{4}{10})] \sin 30^\circ \\
 3(c_1 - c_5) &= [(\frac{1}{7}) - (\frac{5}{11})] \cos 30^\circ \\
 6.c_3 &= (\frac{0}{6}) - (\frac{2}{8}) + (\frac{4}{10}) \\
 3(s_1 + s_5) &= [(\frac{1}{7}) + (\frac{5}{11})] \sin 30^\circ + (\frac{3}{9}) \\
 3(s_1 - s_5) &= [(\frac{2}{8}) + (\frac{4}{10})] \cos 30^\circ \\
 6.s_3 &= (\frac{1}{7}) - (\frac{3}{9}) + (\frac{5}{11}).
 \end{aligned}$$

The values of these coefficients can be easily verified by finding the values of each one from the sum for all the different values of Y as given in the series for $Y_0, Y_1, Y_2, \dots, Y_{11}$.

When we divide the circumference into sixteen parts, each division is 22.5° . We find the values of $Y_0, Y_1, Y_2, \dots, Y_{15}$, as in the case of twelve divisions. To find the values of c_r and s_r , in the case of sixteen divisions, we put

$$\begin{array}{ll}
 (0.8) = Y_0 + Y_8 & (\frac{0}{8}) = Y_0 - Y_8 \\
 (1.9) = Y_1 + Y_9 & (\frac{1}{9}) = Y_1 - Y_9 \\
 (2.10) = Y_2 + Y_{10} & (\frac{2}{10}) = Y_2 - Y_{10} \\
 \vdots & \vdots \\
 (7.15) = Y_7 + Y_{15} & (\frac{7}{15}) = Y_7 - Y_{15}
 \end{array}$$

$$\begin{aligned}
(0.4) &= (0.8) + (4.12) & (0.2) &= (0.4) + (2.6) \\
(1.5) &= (1.9) + (5.13) & (1.3) &= (1.5) + (3.7) \\
(2.6) &= (2.10) + (6.14) \\
(3.7) &= (3.11) + (7.15).
\end{aligned}$$

Then

$$\begin{aligned}
4(c_0 + 2.c_8) &= (0.2) \\
4(c_0 - 2.c_8) &= (1.3) \\
4(c_2 + c_6) &= (0.8) - (4.12) \\
4(c_2 - c_6) &= \{[(1.9) - (5.13)] - [(3.11) - (7.15)]\} \cos 45^\circ \\
4(s_2 + s_6) &= \{[(1.9) - (5.13)] + [(3.11) - (7.15)]\} \cos 45^\circ \\
4(s_2 - s_6) &= (2.10) - (6.14) \\
8.c_4 &= (0.4) - (2.6) \\
8.s_4 &= (1.5) - (3.7) \\
4(c_1 + c_7) &= \left(\frac{0}{8}\right) + \left[\left(\frac{2}{10}\right) - \left(\frac{6}{14}\right)\right] \cos 45^\circ \\
4(c_1 - c_7) &= \left[\left(\frac{1}{9}\right) - \left(\frac{7}{15}\right)\right] \cos 22.^\circ 5 + \left[\left(\frac{3}{11}\right) - \left(\frac{5}{13}\right)\right] \cos 67.^\circ 5 \\
4(c_3 + c_5) &= \left(\frac{0}{8}\right) - \left[\left(\frac{2}{10}\right) - \left(\frac{6}{14}\right)\right] \cos 45^\circ \\
4(c_3 - c_5) &= \left[\left(\frac{1}{9}\right) - \left(\frac{7}{15}\right)\right] \sin 22.^\circ 5 - \left[\left(\frac{3}{11}\right) - \left(\frac{5}{13}\right)\right] \sin 67.^\circ 5 \\
4(s_1 + s_7) &= \left[\left(\frac{1}{9}\right) + \left(\frac{7}{15}\right)\right] \sin 22.^\circ 5 + \left[\left(\frac{3}{11}\right) + \left(\frac{5}{13}\right)\right] \sin 67.^\circ 5 \\
4(s_1 - s_7) &= \left[\left(\frac{2}{10}\right) + \left(\frac{6}{14}\right)\right] \cos 45^\circ + \left(\frac{4}{12}\right) \\
4(s_3 + s_5) &= \left[\left(\frac{1}{9}\right) + \left(\frac{7}{15}\right)\right] \cos 22.^\circ 5 - \left[\left(\frac{3}{11}\right) + \left(\frac{5}{13}\right)\right] \cos 67.^\circ 5 \\
4(s_3 - s_5) &= \left[\left(\frac{2}{10}\right) + \left(\frac{6}{14}\right)\right] \cos 45^\circ - \left(\frac{4}{12}\right).
\end{aligned}$$

When the circumference is divided into twenty-four parts, each part is 15° .

Let

$$\begin{array}{lll}
(0.12) = Y_0 + Y_{12} & (0.6) = (0.12) + (6.18) & \left(\frac{0}{6}\right) = (0.12) - (6.18) \\
(1.13) = Y_1 + Y_{13} & (1.7) = (1.13) + (7.19) & \left(\frac{1}{7}\right) = (1.13) - (7.19) \\
(2.14) = Y_2 + Y_{14} & (2.8) = (2.14) + (8.20) & \left(\frac{2}{8}\right) = (2.14) - (8.20) \\
\vdots & \vdots & \vdots \\
(11.23) = Y_{11} + Y_{23} & (5.11) = (5.17) + (11.23) & \left(\frac{5}{11}\right) = (5.17) - (11.23)
\end{array}$$

Then

$$\begin{aligned}
6(c_0 + 2.c_{12}) &= (0.6) + (2.8) + (4.10) \\
6(c_0 - 2.c_{12}) &= (1.7) + (3.9) + (5.11) \\
6(c_2 + c_{10}) &= \left(\frac{0}{6}\right) + \left[\left(\frac{2}{8}\right) - \left(\frac{4}{10}\right)\right] \sin 30^\circ \\
6(c_2 - c_{10}) &= \left[\left(\frac{1}{7}\right) - \left(\frac{5}{11}\right)\right] \cos 30^\circ \\
6(c_4 + c_8) &= (0.6) - \left[(2.8) + (4.10)\right] \sin 30^\circ \\
6(c_4 - c_8) &= \left[(1.7) + (5.11)\right] \sin 30^\circ - (3.9) \\
6(s_2 + s_{10}) &= \left[\left(\frac{1}{7}\right) + \left(\frac{5}{11}\right)\right] \sin 30^\circ + \left(\frac{3}{9}\right) \\
6(s_2 - s_{10}) &= \left[\left(\frac{2}{8}\right) + \left(\frac{4}{10}\right)\right] \cos 30^\circ \\
6(s_4 + s_8) &= \left[\left(\frac{1}{7}\right) - \left(\frac{5}{11}\right)\right] \cos 30^\circ \\
6(s_4 - s_8) &= \left[\left(\frac{2}{8}\right) - \left(\frac{4}{10}\right)\right] \cos 30^\circ \\
12.c_6 &= \left(\frac{0}{6}\right) - \left(\frac{2}{8}\right) + \left(\frac{4}{10}\right) \\
12.s_6 &= \left(\frac{1}{7}\right) - \left(\frac{3}{9}\right) + \left(\frac{5}{11}\right)
\end{aligned}$$

Further, let

$$\begin{aligned}
\left(\frac{0}{12}\right) &= Y_0 - Y_{12} \\
\left(\frac{1}{13}\right) &= Y_1 - Y_{13} \\
\left(\frac{2}{14}\right) &= Y_2 - Y_{14} \\
&\vdots \quad \quad \quad \vdots \\
\left(\frac{11}{23}\right) &= Y_{11} - Y_{23}
\end{aligned}$$

Then

$$\begin{aligned}
6(c_1 + c_{11}) &= \left(\frac{0}{12}\right) + \left[\left(\frac{2}{14}\right) - \left(\frac{10}{22}\right)\right] \cos 30^\circ + \left[\left(\frac{4}{16}\right) - \left(\frac{8}{20}\right)\right] \cos 60^\circ \\
6(c_1 - c_{11}) &= \left[\left(\frac{1}{13}\right) - \left(\frac{11}{23}\right)\right] \cos 15^\circ + \left[\left(\frac{3}{15}\right) - \left(\frac{9}{21}\right)\right] \cos 45^\circ + \left[\left(\frac{5}{17}\right) - \left(\frac{7}{19}\right)\right] \cos 75^\circ \\
6(c_3 + c_9) &= \left(\frac{0}{12}\right) - \left(\frac{4}{16}\right) + \left(\frac{8}{20}\right) \\
6(c_3 - c_9) &= \left\{ \left(\frac{1}{13}\right) - \left(\frac{11}{23}\right) - \left[\left(\frac{3}{15}\right) - \left(\frac{9}{21}\right)\right] - \left[\left(\frac{5}{17}\right) - \left(\frac{7}{19}\right)\right] \right\} \cos 45^\circ \\
6(c_5 + c_7) &= \left(\frac{0}{12}\right) - \left[\left(\frac{2}{14}\right) - \left(\frac{10}{22}\right)\right] \cos 30^\circ + \left[\left(\frac{4}{16}\right) - \left(\frac{8}{20}\right)\right] \cos 60^\circ \\
6(c_5 - c_7) &= \left[\left(\frac{1}{13}\right) - \left(\frac{11}{23}\right)\right] \sin 15^\circ - \left[\left(\frac{3}{15}\right) - \left(\frac{9}{21}\right)\right] \sin 45^\circ + \left[\left(\frac{5}{17}\right) - \left(\frac{7}{19}\right)\right] \sin 75^\circ \\
6(s_1 + s_{11}) &= \left[\left(\frac{1}{13}\right) + \left(\frac{11}{23}\right)\right] \sin 15^\circ + \left[\left(\frac{3}{15}\right) + \left(\frac{9}{21}\right)\right] \sin 45^\circ + \left[\left(\frac{5}{17}\right) + \left(\frac{7}{19}\right)\right] \sin 75^\circ \\
6(s_1 - s_{11}) &= \left[\left(\frac{2}{14}\right) + \left(\frac{10}{22}\right)\right] \sin 30^\circ + \left[\left(\frac{4}{16}\right) + \left(\frac{8}{20}\right)\right] \sin 60^\circ + \left(\frac{6}{18}\right) \\
6(s_3 + s_9) &= \left\{ \left(\frac{1}{13}\right) + \left(\frac{11}{23}\right) + \left(\frac{3}{15}\right) + \left(\frac{9}{21}\right) - \left[\left(\frac{5}{17}\right) + \left(\frac{7}{19}\right)\right] \right\} \cos 45^\circ \\
6(s_3 - s_9) &= \left(\frac{2}{14}\right) - \left(\frac{6}{18}\right) + \left(\frac{10}{22}\right) \\
6(s_5 + s_7) &= \left[\left(\frac{1}{13}\right) + \left(\frac{11}{23}\right)\right] \cos 15^\circ - \left[\left(\frac{3}{15}\right) + \left(\frac{9}{21}\right)\right] \cos 45^\circ + \left[\left(\frac{5}{17}\right) + \left(\frac{7}{19}\right)\right] \cos 75^\circ \\
6(s_5 - s_7) &= \left[\left(\frac{2}{14}\right) + \left(\frac{10}{22}\right)\right] \sin 30^\circ - \left[\left(\frac{4}{16}\right) + \left(\frac{8}{20}\right)\right] \sin 60^\circ + \left(\frac{6}{18}\right).
\end{aligned}$$

When the circumference is divided into thirty-two parts, each part is $11^\circ.25$

Let

$$\begin{array}{lll}
 (0.16) = Y_0 + Y_{16} & (0.8) = (0.16) + (8.24) & (0.4) = (0.8) + (4.12) \\
 (1.17) = Y_1 + Y_{17} & (1.9) = (1.17) + (9.25) & (1.5) = (1.9) + (5.13) \\
 (2.18) = Y_2 + Y_{18} & (2.10) = (2.18) + (10.26) & (2.6) = (2.10) + (6.14) \\
 \vdots & \vdots & \vdots \\
 \vdots & \vdots & (3.7) = (3.11) + (7.15) \\
 (15.31) = Y_{15} + Y_{31} & (7.15) = (7.23) + (15.31) & (0.2) = (0.4) + (2.6) \\
 & & (1.3) = (1.5) + (3.7) \\
 & (\frac{0}{8}) = (0.16) - (8.24) & (\frac{0}{4}) = (0.8) - (4.12) \\
 & (\frac{1}{9}) = (1.17) - (9.25) & (\frac{1}{5}) = (1.9) - (5.13) \\
 & \vdots & \vdots \\
 & (\frac{7}{15}) = (7.23) - (15.31) & (\frac{3}{7}) = (3.11) - (7.15)
 \end{array}$$

Then

$$\begin{aligned}
 8(c_0 + 2.c_{16}) &= (0.2) + (1.3) \\
 8(c_0 - 2.c_{16}) &= (0.2) - (1.3) \\
 8(c_2 + c_{14}) &= (\frac{0}{8}) + [(\frac{2}{10}) - (\frac{6}{14})] \cos 45^\circ \\
 8(c_2 - c_{14}) &= [(\frac{1}{9}) - (\frac{7}{15})] \cos 22.^\circ 5 + [(\frac{3}{11}) - (\frac{5}{13})] \cos 67.^\circ 5 \\
 8(c_4 + c_{12}) &= (\frac{0}{4}) \\
 8(c_4 - c_{12}) &= [(\frac{1}{5}) - (\frac{3}{7})] \cos 45^\circ \\
 8(c_6 + c_{10}) &= (\frac{0}{8}) - [(\frac{2}{10}) - (\frac{6}{14})] \cos 45^\circ \\
 8(c_6 - c_{10}) &= [(\frac{1}{9}) - (\frac{7}{15})] \sin 22.^\circ 5 - [(\frac{3}{11}) - (\frac{5}{13})] \sin 67.^\circ 5 \\
 16.c_8 &= (0.4) - (2.6) \\
 8(s_2 + s_{14}) &= [(\frac{1}{9}) + (\frac{7}{15})] \sin 22.^\circ 5 + [(\frac{3}{11}) + (\frac{5}{13})] \sin 67.^\circ 5 \\
 8(s_2 - s_{14}) &= [(\frac{2}{10}) - (\frac{6}{14})] \cos 45^\circ + (\frac{4}{12}) \\
 8(s_4 + s_{12}) &= [(\frac{1}{5}) + (\frac{3}{7})] \cos 45^\circ \\
 8(s_4 - s_{12}) &= (\frac{2}{6}) \\
 8(s_6 + s_{10}) &= [(\frac{1}{9}) + (\frac{7}{15})] \cos 22.^\circ 5 - [(\frac{3}{11}) + (\frac{5}{13})] \cos 67.^\circ 5 \\
 8(s_6 - s_{10}) &= [(\frac{2}{10}) - (\frac{6}{14})] \cos 45^\circ - (\frac{4}{12}).
 \end{aligned}$$

Further, let

$$\begin{aligned} \left(\frac{0}{16}\right) &= Y_0 - Y_{16} \\ \left(\frac{1}{17}\right) &= Y_1 - Y_{17} \\ \left(\frac{2}{18}\right) &= Y_2 - Y_{18} \\ &\vdots \\ \left(\frac{15}{31}\right) &= Y_{15} - Y_{31} \end{aligned}$$

And besides, let

$$\begin{aligned} A &= \left[\left(\frac{1}{17}\right) - \left(\frac{15}{31}\right)\right] \cos 11^\circ.25 + \left[\left(\frac{7}{23}\right) - \left(\frac{9}{25}\right)\right] \cos 78^\circ.75 \\ B &= \left[\left(\frac{1}{17}\right) - \left(\frac{15}{31}\right)\right] \sin 11^\circ.25 - \left[\left(\frac{7}{23}\right) - \left(\frac{9}{25}\right)\right] \sin 78^\circ.75 \\ A' &= \left[\left(\frac{2}{18}\right) - \left(\frac{14}{30}\right)\right] \cos 22^\circ.5 + \left[\left(\frac{6}{22}\right) - \left(\frac{10}{26}\right)\right] \cos 67^\circ.5 \\ B' &= \left[\left(\frac{2}{18}\right) - \left(\frac{14}{30}\right)\right] \sin 22^\circ.5 - \left[\left(\frac{6}{22}\right) - \left(\frac{10}{26}\right)\right] \sin 67^\circ.5 \\ A'' &= \left[\left(\frac{3}{19}\right) - \left(\frac{13}{29}\right)\right] \cos 33^\circ.75 + \left[\left(\frac{5}{21}\right) - \left(\frac{11}{27}\right)\right] \cos 56^\circ.25 \\ B'' &= \left[\left(\frac{3}{19}\right) - \left(\frac{13}{29}\right)\right] \sin 33^\circ.75 - \left[\left(\frac{5}{21}\right) - \left(\frac{11}{27}\right)\right] \sin 56^\circ.25 \\ A''' &= \left(\frac{0}{16}\right) + \left[\left(\frac{4}{20}\right) - \left(\frac{12}{28}\right)\right] \cos 45^\circ \\ B''' &= \left(\frac{0}{16}\right) - \left[\left(\frac{4}{20}\right) - \left(\frac{12}{28}\right)\right] \cos 45^\circ \\ C &= \left[\left(\frac{1}{17}\right) + \left(\frac{15}{31}\right)\right] \sin 11^\circ.25 + \left[\left(\frac{7}{23}\right) + \left(\frac{9}{25}\right)\right] \sin 78^\circ.75 \\ D &= \left[\left(\frac{1}{17}\right) + \left(\frac{15}{31}\right)\right] \cos 11^\circ.25 - \left[\left(\frac{7}{23}\right) + \left(\frac{9}{25}\right)\right] \cos 78^\circ.75 \\ C' &= \left[\left(\frac{2}{18}\right) + \left(\frac{14}{30}\right)\right] \sin 22^\circ.5 + \left[\left(\frac{6}{22}\right) + \left(\frac{10}{26}\right)\right] \sin 67^\circ.5 \\ D' &= \left[\left(\frac{2}{18}\right) + \left(\frac{14}{30}\right)\right] \cos 22^\circ.5 - \left[\left(\frac{6}{22}\right) + \left(\frac{10}{26}\right)\right] \cos 67^\circ.5 \\ C'' &= \left[\left(\frac{3}{19}\right) + \left(\frac{13}{29}\right)\right] \sin 33^\circ.75 + \left[\left(\frac{5}{21}\right) + \left(\frac{11}{27}\right)\right] \sin 56^\circ.25 \\ D'' &= \left[\left(\frac{3}{19}\right) + \left(\frac{13}{29}\right)\right] \cos 33^\circ.75 - \left[\left(\frac{5}{21}\right) + \left(\frac{11}{27}\right)\right] \cos 56^\circ.25 \\ C''' &= \left[\left(\frac{4}{20}\right) + \left(\frac{12}{28}\right)\right] \cos 45^\circ + \left(\frac{8}{24}\right) \\ D''' &= \left[\left(\frac{4}{20}\right) + \left(\frac{12}{28}\right)\right] \cos 45^\circ - \left(\frac{8}{24}\right). \end{aligned}$$

Then

$$8(c_1 + c_{15}) = A''' + A'$$

$$8(c_1 - c_{15}) = A + A''$$

$$8(c_3 + c_{13}) = B''' + B'$$

$$8(c_3 - c_{13}) = [A - A'' + B + B''] \cos 45^\circ$$

$$8(c_5 + c_{11}) = B''' - B'$$

$$8(c_5 - c_{11}) = [A - A'' - (B + B'')] \cos 45^\circ$$

$$8(c_7 + c_9) = A''' - A'$$

$$8(c_7 - c_9) = B - B''$$

$$8(s_1 + s_{15}) = C + C''$$

$$8(s_1 - s_{15}) = C''' + C'$$

$$8(s_3 + s_{13}) = [D + D'' - (C - C'')] \cos 45^\circ$$

$$8(s_3 - s_{13}) = D' + D'''$$

$$8(s_5 + s_{11}) = [D + D'' + C - C''] \cos 45^\circ$$

$$8(s_5 - s_{11}) = D' - D'''$$

$$8(s_7 + s_9) = D - D''$$

$$8(s_7 - s_9) = -C''' + C'.$$

The expressions for the determination of the values of c_v and s_v , just given, are found in HANSEN'S *Auseinandersetzung*, Band I, Seite 159-164.

CHAPTER II.

Derivation of the Expressions for BESSEL'S Functions for the Transformation of Trigonometric Series.

The value of $\left(\frac{a}{r}\right)^n$ given thus far is found expressed in a series of terms the arguments of which have the eccentric anomaly of the disturbing body as one constituent. But as the mean anomaly of both bodies is to be employed, it will be necessary to make one transformation; and the next step will be to develop the necessary formulæ for this purpose. HANSEN, in his work entitled *Entwicklung des Products einer Potenz des Radius Vectors et cet.*, has treated the subject of transforming from one anomaly into another very fully; what is here given is based mainly on this work.

Calling c the Napierian base, and putting

$$y = c^{\varepsilon^{\frac{1}{2}} - 1}, \quad y' = c^{\varepsilon'^{\frac{1}{2}} - 1},$$

we have

$$y y' = (\cos \varepsilon + \sqrt{-1} \sin \varepsilon) (\cos \varepsilon' + \sqrt{-1} \sin \varepsilon');$$

also

$$\begin{aligned} y^i y'^{i'} &= (\cos i\varepsilon + \sqrt{-1} \sin i\varepsilon) (\cos i'\varepsilon' + \sqrt{-1} \sin i'\varepsilon') \\ &= \cos (i\varepsilon - i'\varepsilon') + \sqrt{-1} \sin (i\varepsilon - i'\varepsilon'). \end{aligned}$$

Denoting the cosine and sine coefficients of the angles $(i\varepsilon - i'\varepsilon')$ by (i, i', c) and (i, i', s) respectively, the series

$$F = \Sigma \Sigma (i, i', c) \cos (i\varepsilon - i'\varepsilon') - \Sigma \Sigma \sqrt{-1} (i, i', s) \sin (i\varepsilon - i'\varepsilon') \quad (1)$$

can be put in the form

$$F = \frac{1}{2} \Sigma \Sigma \{ (i, i', c) - \sqrt{-1} (i, i', s) \} y^i y'^{i'}. \quad (2)$$

In a similar manner we get

$$F = \frac{1}{2} \cdot \Sigma \Sigma \{ ((i, h', c)) - \sqrt{-1} ((i, h', s)) y^i \cdot z'^{-h'}, \quad (3)$$

where

$$z' = e^{-g' v'^{-1}}.$$

We have now to find the relation between y and z .

Let

$$\begin{aligned} g &= \text{the mean anomaly,} \\ \text{and } \varepsilon &= \text{the eccentric anomaly.} \end{aligned}$$

Then from

$$g = \varepsilon - e \sin \varepsilon,$$

introducing $\sqrt{-1}$, we get

$$g \sqrt{-1} = \varepsilon \sqrt{-1} - e \sin \varepsilon \sqrt{-1}.$$

Since

$$2 \sqrt{-1} \cdot \sin \varepsilon = y - y^{-1},$$

we find

$$g \sqrt{-1} = \varepsilon \sqrt{-1} - \frac{e}{2} (y - y^{-1}).$$

Now from

$$\begin{aligned} z &= e^{g v^{-1}}, \\ y &= e^{\varepsilon v^{-1}}, \end{aligned}$$

we obtain

$$\begin{aligned} g \sqrt{-1} &= \log. z, \\ \varepsilon \sqrt{-1} &= \log. y, \end{aligned}$$

and

$$\frac{e}{2} (y - y^{-1}) = \log. \left(c^{\frac{e}{2}} (y - y^{-1}) \right). \quad (4)$$

Thus

$$g \sqrt{-1} = \log. z = \log. \left(y \cdot c^{-\frac{e}{2}} (y - y^{-1}) \right);$$

and hence

$$z = y \cdot c^{-\frac{e}{2}} (y - y^{-1}). \quad (5)$$

From

$$z = y \cdot c^{-\frac{e}{2}} (y - y^{-1}),$$

we have

$$z^h = y^h \cdot c^{-\frac{he}{2}} (y - y^{-1}), \quad (6)$$

and

$$y^i = z^i \cdot c^{\frac{ie}{2}} (y - y^{-1}). \quad (7)$$

Let $\frac{e}{2}$ be denoted by λ ; then

$$c^{-\frac{he}{2}} (y - y^{-1}) = c^{-h\lambda} \cdot y \cdot c^{h\lambda} \cdot y^{-1}, \quad (8)$$

and

$$c^{\frac{ie}{2}} (y - y^{-1}) = c^{i\lambda} \cdot y \cdot c^{-i\lambda} \cdot y^{-1}. \quad (9)$$

But

$$\begin{aligned} c^{-h\lambda} \cdot y \cdot c^{h\lambda} \cdot y^{-1} &= \left(1 - h\lambda \cdot y + \frac{h^2\lambda^2}{1.2} \cdot y^2 - \frac{h^3\lambda^3}{1.2.3} \cdot y^3 + \frac{h^4\lambda^4}{1.2.3.4} \cdot y^4 \mp \text{etc.} \right) \\ &\quad \left(1 + h\lambda \cdot y^{-1} + \frac{h^2\lambda^2}{1.2} \cdot y^{-2} + \frac{h^3\lambda^3}{1.2.3} \cdot y^{-3} + \frac{h^4\lambda^4}{1.2.3.4} \cdot y^{-4} + \text{etc.} \right) \end{aligned}$$

and

$$e^{i\lambda y} \cdot e^{-i\lambda y^{-1}} = \left(1 + i\lambda \cdot y + \frac{i^2 \lambda^2}{1.2} \cdot y^2 + \frac{i^3 \lambda^3}{1.2.3} \cdot y^3 + \frac{i^4 \lambda^4}{1.2.3.4} \cdot y^4 + \text{etc.}\right) \\ \left(1 - i\lambda \cdot y^{-1} + \frac{i^2 \lambda^2}{1.2} \cdot y^{-2} - \frac{i^3 \lambda^3}{1.2.3} \cdot y^{-3} + \frac{i^4 \lambda^4}{1.2.3.4} \cdot y^{-4} + \text{etc.}\right)$$

Performing the operations indicated, we have

$$e^{-h \frac{c}{2} (y - y^{-1})} = \left(1 - h^2 \lambda^2 + \frac{h^4 \lambda^4}{1^2.2^2} - \frac{h^6 \lambda^6}{1^2.2^2.3^2} + \frac{h^8 \lambda^8}{1^2.2^2.3^2.4^2} \mp \text{etc.}\right) \\ \left(h\lambda - \frac{h^3 \lambda^3}{1^2.2} + \frac{h^5 \lambda^5}{1^2.2^2.3} - \frac{h^7 \lambda^7}{1^2.2^2.3^2.4} \pm \text{etc.}\right) (y^{-1} - y) \\ \left(+ \frac{h^2 \lambda^2}{1.2} - \frac{h^4 \lambda^4}{1^2.2.3} + \frac{h^6 \lambda^6}{1^2.2^2.3.4} \mp \text{etc.}\right) (y^{-2} + y^2) \\ \left(+ \frac{h^3 \lambda^3}{1.2.3} - \frac{h^5 \lambda^5}{1^2.2.3.4} \pm \text{etc.}\right) (y^{-3} - y^3) \\ \left(+ \frac{h^4 \lambda^4}{1.2.3.4} \mp \text{etc.}\right) (y^{-4} + y^4); \\ + \dots \\ + \frac{h^m \lambda^m}{1.2..m} \left(1 - \frac{h^2 \lambda^2}{1.m+1} + \frac{h^4 \lambda^4}{1.2.m+1.m+2} \mp \text{etc.}\right) y^m \\ e^{i \frac{c}{2} (y - y^{-1})} = 1 - i^2 \lambda^2 + \frac{i^4 \lambda^4}{1^2.2^2} - \frac{i^6 \lambda^6}{1^2.2^2.3^2} + \frac{i^8 \lambda^8}{1^2.2^2.3^2.4^2} \mp \text{etc.} \\ \left(+ i\lambda - \frac{i^3 \lambda^3}{1^2.2} + \frac{i^5 \lambda^5}{1^2.2^2.3} - \frac{i^7 \lambda^7}{1^2.2^2.3^2.4} \pm \text{etc.}\right) (y - y^{-1}) \\ \left(+ \frac{i^2 \lambda^2}{1.2} - \frac{i^4 \lambda^4}{1^2.2.3} + \frac{i^6 \lambda^6}{1^2.2^2.3.4} \mp \text{etc.}\right) (y^2 + y^{-2}) \\ \left(+ \frac{i^3 \lambda^3}{1.2.3} - \frac{i^5 \lambda^5}{1^2.2.3.4} \pm \text{etc.}\right) (y^3 - y^{-3}) \\ \left(+ \frac{i^4 \lambda^4}{1.2.3.4} \mp \text{etc.}\right) (y^4 + y^{-4}) \\ + \dots$$

As we may write h in place of i , we have, thus, also given the value of $c^{h\frac{e}{2}}(y-y^{-1})$.

Now put

$$\left. \begin{aligned} c^{-h\frac{e}{2}}(y-y^{-1}) &= \sum_{-\infty}^{+\infty} J_{-h\lambda}^{(-m)} \cdot y^{-m}, \\ c^{h\frac{e}{2}}(y-y^{-1}) &= \sum_{-\infty}^{+\infty} J_{-h\lambda}^{(m)} \cdot y^m. \end{aligned} \right\} \quad (10)$$

Then, from the preceding developments, we see that

$$\left. \begin{aligned} J_{h\lambda}^{(-m)} &= (-1)^m \cdot J_{h\lambda}^{(m)}, \\ J_{-h\lambda}^{(m)} &= (-1)^m \cdot J_{h\lambda}^{(m)}, \\ J_{-h\lambda}^{(-m)} &= J_{h\lambda}^{(m)}. \end{aligned} \right\} \quad (11)$$

Again

$$\left. \begin{aligned} \sum_{-\infty}^{+\infty} J_{-h\lambda}^{(-m)} \cdot y^{-m} &= J_{-h\lambda}^{(0)} + J_{-h\lambda}^{(-1)} \cdot y^{-1} + J_{-h\lambda}^{(-2)} \cdot y^{-2} + J_{-h\lambda}^{(-3)} \cdot y^{-3} + \text{etc.} \\ &\quad + J_{-h\lambda}^{(1)} \cdot y + J_{-h\lambda}^{(2)} \cdot y^2 + J_{-h\lambda}^{(3)} \cdot y^3 + \text{etc.} \end{aligned} \right\} \quad (12)$$

$$\left. \begin{aligned} \sum_{-\infty}^{+\infty} J_{h\lambda}^{(m)} \cdot y^m &= J_{h\lambda}^{(0)} + J_{h\lambda}^{(1)} \cdot y + J_{h\lambda}^{(2)} \cdot y^2 + J_{h\lambda}^{(3)} \cdot y^3 + \text{etc.} \\ &\quad + J_{h\lambda}^{(-1)} \cdot y^{-1} + J_{h\lambda}^{(-2)} \cdot y^{-2} + J_{h\lambda}^{(-3)} \cdot y^{-3} + \text{etc.} \end{aligned} \right\} \quad (13)$$

Comparing the values of $\sum_{-\infty}^{+\infty} J_{-h\lambda}^{(-m)} \cdot y^{-m}$ and $c^{-h\frac{e}{2}}(y-y^{-1})$ we have

$$\begin{aligned} J_{-h\lambda}^{(-1)} &= J_{h\lambda}^{(1)} = h\lambda - \frac{h^3\lambda^3}{1^2 \cdot 2} + \frac{h^5\lambda^5}{1^2 \cdot 2^2 \cdot 3} - \frac{h^7\lambda^7}{1^2 \cdot 2^2 \cdot 3^2 \cdot 4} \pm \text{etc.,} \quad \text{for } y^{-1}, \\ -J_{-h\lambda}^{(1)} &= J_{h\lambda}^{(1)} = h\lambda - \frac{h^3\lambda^3}{1^2 \cdot 2} + \frac{h^5\lambda^5}{1^2 \cdot 2^2 \cdot 3} - \frac{h^7\lambda^7}{1^2 \cdot 2^2 \cdot 3^2 \cdot 4} \pm \text{etc.,} \quad \text{for } y^1, \\ J_{-h\lambda}^{(-2)} &= J_{h\lambda}^{(2)} = \frac{h^2\lambda^2}{1 \cdot 2} - \frac{h^4\lambda^4}{1^2 \cdot 2 \cdot 3} + \frac{h^6\lambda^6}{1^2 \cdot 2^2 \cdot 3 \cdot 4} \mp \text{etc.,} \quad \text{for } y^{-2}, \\ J_{-h\lambda}^{(2)} &= J_{h\lambda}^{(2)} = \frac{h^2\lambda^2}{1 \cdot 2} - \frac{h^4\lambda^4}{1^2 \cdot 2 \cdot 3} + \frac{h^6\lambda^6}{1^2 \cdot 2^2 \cdot 3 \cdot 4} \mp \text{etc.,} \quad \text{for } y^2, \\ \text{etc.} &= \text{etc.} = \text{etc.} \end{aligned}$$

Comparing the values of $\sum_{-\infty}^{+\infty} J_{h\lambda}^{(m)} \cdot y^m$ and $c^{h\frac{e}{2}(y-y^{-1})}$, we get the same expressions for y^m and y^{-m} .

We see from the values of $J_{h\lambda}^{(1)}$, $J_{h\lambda}^{(2)}$, etc., found above, that the general term is

$$\begin{aligned} J_{h\lambda}^{(m)} &= \frac{h^m \lambda^m}{1.2\dots m} - \frac{h^{m+2} \lambda^{m+2}}{1^2.2\dots m.m+1} + \frac{h^{m+4} \lambda^{m+4}}{1^2.2^2\dots m.m+1.m+2} \mp \text{etc.} \\ &= \frac{h^m \lambda^m}{1.2\dots m} \left(1 - \frac{h^2 \lambda^2}{1.m+1} + \frac{h^4 \lambda^4}{1.2.m+1.m+2} \mp \text{etc.} \right) \end{aligned} \quad (14)$$

Further, we have

$$z^h = c^{-h\frac{e}{2}(y-y^{-1})} \cdot y^h = J_{h\lambda}^{(m)} \cdot y^{-m} \cdot y^h;$$

and, by putting $m = h - i$, this becomes

$$z^h = J_{h\lambda}^{(h-i)} \cdot y^i \quad (15)$$

Let

$$\left. \begin{aligned} z^h &= \sum_{-\infty}^{+\infty} Q_i^{(h)} \cdot y^i \\ y^i &= \sum_{-\infty}^{+\infty} P_h^{(i)} \cdot z^h \end{aligned} \right\} \quad (16)$$

Multiplying the second of these equations by $z^{-h} \cdot dg$, we obtain

$$y^i \cdot z^{-h} \cdot dg = \sum_{-\infty}^{+\infty} P_h^{(i)} \cdot dg.$$

Integrating between the limits $+\pi$ and $-\pi$, we have

$$P_h^{(i)} = \frac{1}{2\pi} \int_{-\pi}^{+\pi} y^i \cdot z^{-h} \cdot dg \quad (17)$$

From

$$z = e^{g\sqrt{-1}} = \cos g + \sqrt{-1} \sin g,$$

we have

$$dz = (-\sin g + \sqrt{-1} \cdot \cos g) dg;$$

also

$$z \sqrt{-1} = \sqrt{-1} \cos g - \sin g.$$

Therefore

$$dz = z \sqrt{-1} \cdot dg,$$

and (17) becomes

$$P_h^{(i)} = \frac{1}{2\pi\sqrt{-1}} \int_{e^{-\pi\sqrt{-1}}}^{e^{+\pi\sqrt{-1}}} y^i \cdot z^{-h-1} \cdot dz.$$

In like manner we find

$$Q_i^{(h)} = \frac{1}{2\pi\sqrt{-1}} \int_{e^{-\pi\sqrt{-1}}}^{e^{+\pi\sqrt{-1}}} z^h \cdot y^{-i-1} \cdot dy.$$

Integrating by parts we have

$$Q_i^{(h)} = \frac{1}{2\pi\sqrt{-1}} \cdot \frac{h}{i} \int_{e^{-\pi\sqrt{-1}}}^{e^{+\pi\sqrt{-1}}} y^{-i} \cdot z^{h-1} \cdot dz. \quad (18)$$

Comparing this value of $Q_i^{(h)}$ with that of $P_h^{(i)}$, we obtain

$$i \cdot Q_i^{(h)} = h \cdot P_{-h}^{(-i)} = h \cdot P_h^{(i)},$$

or

$$P_h^{(i)} = \frac{i}{h} \cdot Q_i^{(h)} = \frac{i}{h} \cdot J_{h\lambda}^{(h-i)}. \quad (19)$$

Thus we have, between the mean and the eccentric anomaly, the relations

$$\left. \begin{aligned} z^h &= J_{h\lambda}^{(h-i)} \cdot y^i \\ y^i &= J_{h\lambda}^{(h-i)} \cdot z^h \end{aligned} \right\} \quad (20)$$

In the application of these relations, since

$$y'^{-i} = \Sigma P_{-h'}^{(-i')} \cdot z'^{-h'},$$

the expression for F is changed from

$$F = \frac{1}{2} \Sigma \Sigma \{ (i, i', c) - \sqrt{-1} (i, i', s) \} y^i \cdot y'^{-i'}$$

into

$$F = \frac{1}{2} \Sigma \Sigma \{ (i, i', c) - \sqrt{-1} (i, i', s) \} y^i \cdot \Sigma P_{-h'}^{-i'} \cdot z'^{-h'}.$$

The other value of F is

$$F = \frac{1}{2} \Sigma \Sigma \{ ((i, h', c)) - \sqrt{-1} ((i, h', s)) \} y^i \cdot z'^{-h'}.$$

A comparison of these two values gives

$$((i, h', c)) = \Sigma P_{-h'}^{(-i')} (i, i', c) = \Sigma \cdot \frac{i'}{h'} \cdot J_{h' h'}^{(h'-i')} (i, i', c) \quad (21)$$

In transforming from the series indicated by (i, i', c) into that of $((i, h', c))$, it is evident that h' is constant in each individual case, and i' is the variable.

Thus we find, beginning with $i' = h'$,

$$\begin{aligned} ((i, h', c)) &= \frac{h'}{h'} \cdot J_{h' h'}^{(h'-h')} (i, h', c) + \frac{h'-1}{h'} \cdot J_{h' h'}^{(h'-(h'-1))} (i, h'-1, c) + \text{etc.} \\ &\quad + \frac{h'+1}{h'} \cdot J_{h' h'}^{(h'-(h'+1))} (i, h'+1, c) + \text{etc.} \end{aligned}$$

To transform from $((i, h', c))$ into (i, i', c)

we have

$$(i, i', c) = \Sigma Q_{-i}^{(-h')} ((i, h', c)) = \Sigma J_{h' \lambda'}^{(h' - i')} ((i, h', c)).$$

Here, i' is the constant, and h' the variable; and for the different values of h' , beginning with $h' = i'$,

we find

$$\begin{aligned} (i, i', c) &= J_{i' \lambda'}^{(0)} ((i, i', c)) + J_{(i'-1) \lambda'}^{(i'-1) - i'} ((i, i' - 1, c)) + \text{etc.} \\ &\quad + J_{(i'+1) \lambda'}^{(i'+1) - i'} ((i, i' + 1, c)) + \text{etc.} \end{aligned}$$

The expression

$$J_{h\lambda}^{(m)} = \frac{h^m \lambda^m}{1.2..m} \left(1 - \frac{h^2 \lambda^2}{1.m+1} + \frac{h^4 \lambda^4}{1.2.m+1.m+2} - \frac{h^6 \lambda^6}{1.2.3.m+1.m+2.m+3} \pm \text{etc.} \right)$$

enables us to find the value of $J_{h\lambda}^{(m)}$ for all values of m .

A simpler method can be obtained in the following manner:

Putting $c^{h\frac{e}{2}(y-y^{-1})}$ in the form

$$c^{h\frac{e}{2}(y-y^{-1})} = J_{h\frac{e}{2}}^{(0)} + J_{h\frac{e}{2}}^{(1)} \cdot y - J_{h\frac{e}{2}}^{(-1)} \cdot y^{-1} + J_{h\frac{e}{2}}^{(2)} \cdot y^2 + J_{h\frac{e}{2}}^{(-2)} \cdot y^{-2} + \text{etc.}$$

we have, for the differential coefficient relative to y ,

$$h\frac{e}{2}(1+y^{-2}) \cdot c^{h\frac{e}{2}(y-y^{-1})} = J_{h\frac{e}{2}}^{(1)} + 2 \cdot J_{h\frac{e}{2}}^{(2)} \cdot y \pm \text{etc.} + J_{h\frac{e}{2}}^{(-1)} \cdot y^{-2} - 2 J_{h\frac{e}{2}}^{(-2)} \cdot y^{-3} \pm \text{etc.}$$

If we multiply the second member of the first equation by $h\frac{e}{2}(1+y^{-2})$, we have an expression equal to the second member of the second expression, and by comparing the two we find

$$h\frac{e}{2} \left\{ J_{h\frac{e}{2}}^{(m+1)} + J_{h\frac{e}{2}}^{(m-1)} \right\} = m \cdot J_{h\frac{e}{2}}^{(m)} \quad (22)$$

Let

$$\frac{J_{h\frac{e}{2}}^{(m)}}{J_{h\frac{e}{2}}^{(m-1)}} = p_m; \quad (23)$$

then

$$J_{h\frac{e}{2}}^{(m)} = J_{h\frac{e}{2}}^{(m-1)} \cdot p_m.$$

From this general expression we find

$$\begin{aligned} J_{h\frac{e}{2}}^{(1)} &= J_{h\frac{e}{2}}^{(0)} \cdot p_1 \\ J_{h\frac{e}{2}}^{(2)} &= J_{h\frac{e}{2}}^{(1)} \cdot p_2 = J_{h\frac{e}{2}}^{(0)} \cdot p_1 \cdot p_2 \end{aligned} \quad (24)$$

$$\text{etc.} = \text{etc.} = \text{etc.}$$

From the values here given, since $\frac{J_{h\frac{e}{2}}^{(m)}}{J_{h\frac{e}{2}}^{(m-1)}}$ is put equal to p_m , we have, by increas-

ing m by unity,

$$\frac{J_{h\frac{e}{2}}^{(m+1)}}{J_{h\frac{e}{2}}^{(m)}} = p_m \cdot p_{m+1}$$

Putting $\frac{m}{h\frac{e}{2}} = r_m$, equation (22)

takes the form

$$p_m \cdot p_{m+1} + 1 = r_m \cdot p_m.$$

From this we find

$$\begin{aligned} p_m &= \frac{1}{r_m - p_{m+1}} \\ &= \frac{1}{r_m} - \frac{1}{r_{m+1}} - \frac{1}{r_{m+2}} - \text{etc.} \end{aligned}$$

We also have

$$\frac{1}{p_m} = r_m - p_{m+1}, \quad (25)$$

a form more convenient in the applications.

The general expression for $J_{h\frac{e}{2}}^{(m)}$ is

$$J_{h\frac{e}{2}}^{(m)} = J_{h\frac{e}{2}}^{(0)} \cdot p_1 \cdot p_2 \cdot p_3 \cdots p_m, \quad (26)$$

where

$$J_{h\frac{e}{2}}^{(0)} = 1 - \frac{l^2}{1^2} + \frac{l^4}{1^2 \cdot 2^2} - \frac{l^6}{1^2 \cdot 2^2 \cdot 3^2} \pm \text{etc.}, \quad (27)$$

if we put $l = h\lambda$.

From the expression

$$((i, h', c)) = \Sigma P_{-h'}^{(-i')} (i, i', c) = \Sigma \frac{i}{h'} J_{h'h'}^{(h'-i')} (i, i', c)$$

it is evident that when $h' = 0$, or when both i' and h' are zero, this expression cannot be employed.

To find the values for these exceptional cases let us resume the equation

$$P_h^{(i)} = \frac{1}{2\pi\sqrt{-1}} \int_{e^{-\pi\sqrt{-1}}}^{e^{+\pi\sqrt{-1}}} y^i z^{-h-1} dz.$$

When $h = 0$ we have

$$P_0^{(i)} = \frac{1}{2\pi\sqrt{-1}} \int_{e^{-\pi\sqrt{-1}}}^{e^{+\pi\sqrt{-1}}} y^i z^{-1} dz$$

The equation

$$z = y \cdot e^{-\frac{e}{2i}(y - y^{-1})}$$

gives

$$\frac{dz}{z} = \frac{dy}{y} - \frac{e}{2} (1 + y^{-2}) dy. \quad (28)$$

Hence

$$P_0^{(i)} = \frac{1}{2\pi\sqrt{-1}} \int_{e^{-\pi\sqrt{-1}}}^{e^{+\pi\sqrt{-1}}} (y^{i-1} - \frac{e}{2} y^i - \frac{e}{2} y^{i-2}) dy.$$

When p is a whole number

$$\int_{e^{-\pi\sqrt{-1}}}^{e^{+\pi\sqrt{-1}}} y^p dy = 0,$$

except when $p = 1$, when this integral is $2\pi\sqrt{-1}$.

Hence it follows that

$$P_0^{(1)} = P_0^{(-1)} = -\frac{1}{2}e.$$

When $i = 0$, we have

$$P_0^{(0)} = 1.$$

Using the expression

$$\begin{aligned} ((i, h', c)) = \Sigma \cdot P_{-h'}^{(-i')} (i, i', c) &= P_{-h'}^{(-i')} (i, i', c) + P_{-h'}^{(-i'-1)} (i, i' + 1, c) \\ &\quad + P_{-h'}^{(-i+1)} (i, i' - 1, c), \end{aligned}$$

we have

$$((0, 0, c)) = (0, 0, c) - 2\lambda' (0, 1, c)$$

for the constant term, the double value of this term being employed.

For $h' = 0$, we have

$$\begin{aligned} ((1, 0, c)) &= (1, 0, c) - \lambda' (1, 1, c) - \lambda' (1, -1, c) \\ ((1, 0, s)) &= (1, 0, s) - \lambda' (1, 1, s) - \lambda' (1, -1, s) \\ ((2, 0, c)) &= (2, 0, c) - \lambda' (2, 1, c) - \lambda' (2, -1, c) \\ ((2, 0, s)) &= (2, 0, s) - \lambda' (2, 1, s) - \lambda' (2, -1, s) \\ &\text{etc.} = \text{etc.} \end{aligned}$$

In what precedes we have put

$$\begin{aligned} g &= \text{the mean anomaly,} \\ \varepsilon &= \text{the eccentric anomaly,} \\ c &= \text{the Naperian base,} \\ z &= e^{g\sqrt{-1}}, \\ y &= e^{\varepsilon\sqrt{-1}}, \end{aligned}$$

and obtain

$$\begin{aligned} z^h &= y^h \cdot e^{-h\frac{e}{2}(y-y^{-1})}, \\ y^i &= z^i \cdot e^{i\frac{e}{2}(y-y^{-1})}; \end{aligned}$$

where $e^{-h\frac{e}{2}(y-y^{-1})}$ is expressed in a series, the general term of which is

$$h^m \lambda^m \left(1 - \frac{h^2 \lambda^2}{1.m+1} + \frac{h^4 \lambda^4}{1.2.m+1.m+2} - \frac{h^6 \lambda^6}{1.2.3.m+1.m+2.m+3} \pm \text{etc.} \right) y^m.$$

Thus

$$z^h = y^h \cdot h^m \lambda^m \left(1 - \frac{h^2 \lambda^2}{1.m+1} + \frac{h^4 \lambda^4}{1.2.m+1.m+2} - \frac{h^6 \lambda^6}{1.2.3.m+1.m+2.m+3} \pm \text{etc.} \right) y^m.$$

We have also put

$$\begin{aligned} e^{-h\frac{e}{2}(y-y^{-1})} &= \sum_{-\infty}^{+\infty} J_{-h\lambda}^{(-m)} \cdot y^{-m}, \\ e^{h\frac{e}{2}(y-y^{-1})} &= \sum_{-\infty}^{+\infty} J_{h\lambda}^{(m)} \cdot y^m; \end{aligned}$$

and since

$$J_{-h\lambda}^{(-m)} = J_{h\lambda}^{(m)},$$

have found

$$\begin{aligned} z^h &= J_{h\lambda}^{(m)} \cdot y^{-m} \cdot y^h, \\ &= J_{h\lambda}^{(h-i)} \cdot y^i, \end{aligned}$$

if

$$m = h - i.$$

Again supposing

$$\begin{aligned} z^h &= \sum_{-\infty}^{+\infty} Q_i^{(h)} \cdot y^i, \\ y^i &= \sum_{-\infty}^{+\infty} P_h^{(i)} \cdot z^h, \end{aligned}$$

we have found

$$P_h^{(i)} = \frac{i}{h} \cdot Q_i^{(h)} = \frac{i}{h} \cdot J_{h\lambda}^{(h-i)}.$$

Thus we have

$$\begin{aligned} z^h &= J_{h\lambda}^{(h-i)} \cdot y^i, \\ &= J_{h\lambda}^{(h-i)} \left[\cos i\varepsilon + \sin i\varepsilon \sqrt{-1} \right]; \\ y^i &= \frac{i}{h} \cdot J_{h\lambda}^{(h-i)} \cdot z^h \\ &= \frac{i}{h} \cdot J_{h\lambda}^{(h-i)} \left[\cos hg + \sin hg \sqrt{-1} \right]. \end{aligned}$$

Equating real and imaginary terms, we have

$$\left. \begin{aligned} \cos i\varepsilon &= \frac{i}{h} \cdot \sum_{h=-\infty}^{h=\infty} J_{h\lambda}^{(h-i)} \cdot \cos hg, \\ \sin i\varepsilon &= \frac{i}{h} \cdot \sum_{h=-\infty}^{h=\infty} J_{h\lambda}^{(h-i)} \cdot \sin hg. \end{aligned} \right\} \quad (29)$$

We notice that

$$\begin{aligned} P_0^{(1)} &= P_0^{(-1)} = -\frac{1}{2}e, \\ P_0^{(0)} &= 1. \end{aligned}$$

For all other values of i

$$P_0^{(i)} = 0.$$

If a large number of the J functions are needed they are computed by means of equations (24) to (27), as shown in the example given in Chapter V.

If we wish to determine any of them independently we have from

$$\begin{aligned} J_{h\lambda}^{(m)} &= \frac{h^m \lambda^m}{1.2\dots m} \left[1 - \frac{h^2 \lambda^2}{1.m+1} + \frac{h^4 \cdot \lambda^4}{1.2.m+1.m+2} - \frac{h^6 \cdot \lambda^6}{1.2.3.m+1.m+2.m+3} \pm \text{etc.} \right], \\ J_{h\frac{e}{2}}^{(0)} &= \left[1 - \frac{h^2}{1} \cdot \frac{e^2}{4} + \frac{h^4}{4} \cdot \frac{e^4}{16} - \frac{h^6}{36} \cdot \frac{e^6}{64} \pm \text{etc.} \right] \\ J_{h\frac{e}{2}}^{(1)} &= \frac{h\frac{e}{2}}{1} \left[1 - \frac{h^2}{2} \cdot \frac{e^2}{4} + \frac{h^4}{12} \cdot \frac{e^4}{16} - \frac{h^6}{144} \cdot \frac{e^6}{64} \pm \text{etc.} \right] \\ J_{h\frac{e}{2}}^{(2)} &= \frac{(h\frac{e}{2})^2}{1.2} \left[1 - \frac{h^2}{3} \cdot \frac{e^2}{4} + \frac{h^4}{24} \cdot \frac{e^4}{16} \mp \text{etc.} \right] \\ J_{h\frac{e}{2}}^{(3)} &= \frac{(h\frac{e}{2})^3}{1.2.3} \left[1 - \frac{h^2}{4} \cdot \frac{e^2}{4} + \frac{h^4}{40} \cdot \frac{e^4}{16} \mp \text{etc.} \right] \\ J_{h\frac{e}{2}}^{(4)} &= \frac{(h\frac{e}{2})^4}{1.2.3.4} \left[1 - \frac{h^2}{5} \cdot \frac{e^2}{4} \pm \text{etc.} \right] \end{aligned} \quad (30)$$

In these expressions we have written for λ its value $\frac{1}{2}e$.

Since h has all values from $h = +\infty$ to $-\infty$ we find any value of $J_{h\lambda}^{(m)}$ by attributing proper values to h .

From equations (29) we find the values of the functions $\cos i\varepsilon$, $\sin i\varepsilon$, in terms of $\cos hg$, $\sin hg$, and the J functions just given; always noting that when $h = 0$, we have only for $i = \pm 1$, $-\frac{1}{2}e$ as the value of the function.

We can employ equation (22) when only a few functions are needed, or as a check.

It may be of value to have y^i in terms of z^h and the J functions. From the second of equations (20) we have

$$\begin{aligned}
 y^{+1} &= -\lambda + J_{\lambda}^{(0)} \cdot z + \frac{1}{2} J_{2\lambda}^{(1)} \cdot z^2 + \frac{1}{3} J_{3\lambda}^{(2)} \cdot z^3 + \text{etc.} \\
 &\quad - J_{\lambda}^{(2)} \cdot z^{-1} - \frac{1}{2} J_{2\lambda}^{(3)} \cdot z^{-2} - \frac{1}{3} J_{3\lambda}^{(4)} \cdot z^{-3} - \text{etc.} \\
 y^{-1} &= -\lambda + J_{\lambda}^{(0)} \cdot z^{-1} + \frac{1}{2} J_{2\lambda}^{(1)} \cdot z^{-2} + \frac{1}{3} J_{3\lambda}^{(2)} \cdot z^{-3} + \text{etc.} \\
 &\quad - J_{\lambda}^{(2)} \cdot z - \frac{1}{2} J_{2\lambda}^{(3)} \cdot z^2 - \frac{1}{3} J_{3\lambda}^{(4)} \cdot z^3 - \text{etc.} \\
 y^{+2} &= -\frac{2}{1} J_{\lambda}^{(1)} \cdot z + \frac{2}{2} J_{2\lambda}^{(0)} \cdot z^2 + \frac{2}{3} J_{3\lambda}^{(1)} \cdot z^3 + \text{etc.} \\
 &\quad - \frac{2}{1} J_{\lambda}^{(3)} \cdot z^{-1} - \frac{2}{2} J_{2\lambda}^{(4)} \cdot z^{-2} - \frac{2}{3} J_{3\lambda}^{(5)} \cdot z^{-3} - \text{etc.} \\
 y^{-2} &= -\frac{2}{1} J_{\lambda}^{(1)} \cdot z^{-1} + \frac{2}{2} J_{2\lambda}^{(0)} \cdot z^{-2} + \frac{2}{3} J_{3\lambda}^{(1)} \cdot z^{-3} + \text{etc.} \\
 &\quad - \frac{2}{1} J_{\lambda}^{(3)} \cdot z - \frac{2}{2} J_{2\lambda}^{(4)} \cdot z^2 - \frac{2}{3} J_{3\lambda}^{(5)} \cdot z^3 - \text{etc.}
 \end{aligned}$$

Then from

$$\begin{aligned}
 y^i + y^{-i} &= 2 \cos i\varepsilon \\
 y^i - y^{-i} &= 2 \sqrt{-1} \cdot \sin i\varepsilon
 \end{aligned}$$

we find the values of $\cos \varepsilon$, $\sin \varepsilon$, $\cos 2\varepsilon$, $\sin 2\varepsilon$, etc.

In case of the sine, as for example when $i = 1$, we have

$$y - y^{-1} = 2 \sqrt{-1} \sin \varepsilon; \text{ but in } z - z^{-1} = 2 \sqrt{-1} \sin g,$$

we have the same factor, $2 \sqrt{-1}$, in the second member of the equation.

From

$$r = a(1 - e \cos \varepsilon)$$

we find

$$\left(\frac{r}{a}\right)^2 = 1 - 2e \cos \varepsilon + e^2 \cos^2 \varepsilon$$

$$\left(\frac{a}{r}\right)^2 = 1 + 2e \cos \varepsilon + 3e^2 \cos^2 \varepsilon + 4e^3 \cos^3 \varepsilon + \text{etc.}$$

For $\left(\frac{r}{a}\right)^2$ we have

$$\left(\frac{r}{a}\right)^2 = 1 + \frac{1}{2}e^2 - 2e \cos \varepsilon + \frac{1}{2}e^2 \cos 2\varepsilon$$

But

$$\frac{d}{dg} \left(\frac{r^2}{a^2}\right) = 2e \sin \varepsilon (1 - e \cos \varepsilon) \frac{d\varepsilon}{dg} = 2e \sin \varepsilon,$$

and

$$\sin \varepsilon = \left[J_{\lambda}^{(0)} + J_{\lambda}^{(2)} \right] \sin g + \frac{1}{2} \left[J_{2\lambda}^{(1)} + J_{2\lambda}^{(3)} \right] \sin 2g + \frac{1}{3} \left[J_{3\lambda}^{(2)} + J_{3\lambda}^{(4)} \right] \sin 3g + \text{etc.}$$

Multiplying by $2e \cdot dg$ we have for the integral of $\frac{d}{dg} \left(\frac{r^2}{a^2}\right)$

$$\frac{r^2}{a^2} = c - \frac{2e}{1} \left[J_{\lambda}^{(0)} + J_{\lambda}^{(2)} \right] \cos g - \frac{2e}{4} \left[J_{2\lambda}^{(1)} + J_{2\lambda}^{(3)} \right] \cos 2g - \frac{2e}{9} \left[J_{3\lambda}^{(2)} + J_{3\lambda}^{(4)} \right] \cos 3g - \text{etc.}$$

where $c = 1 + \frac{3}{2}e^2$.

By means of (22) this becomes

$$\left(\frac{r}{a}\right)^2 = 1 + \frac{3}{2}e^2 - \frac{4}{1}J_{\lambda}^{(1)} \cos g - \frac{4}{4}J_{2\lambda}^{(2)} \cos 2g - \frac{4}{9}J_{3\lambda}^{(3)} \cos 3g - \text{etc.}$$

In case of $\left(\frac{r}{a}\right)^{-2}$, we have

$$3e^2 \cdot \cos^2 \varepsilon = \frac{3}{2}e^2 (1 + \cos 2\varepsilon), \quad 4e^3 \cos^3 \varepsilon = e^3 (3 \cos \varepsilon + \cos 3\varepsilon),$$

$$5e^4 \cdot \cos^4 \varepsilon = \frac{5}{8}e^4 (3 + 4 \cos 2\varepsilon + \cos 4\varepsilon), \quad 6e^5 \cdot \cos^5 \varepsilon = \frac{6}{16}e^5 (10 \cos \varepsilon + 5 \cos 3\varepsilon + \cos 5\varepsilon),$$

$$7e^6 \cos^6 \varepsilon = \frac{7}{32}e^6 (10 + 15 \cos 2\varepsilon + 6 \cos 4\varepsilon + \text{etc.})$$

and hence

$$\begin{aligned} \left(\frac{r}{a}\right)^{-2} &= 1 + \frac{3}{2}e^2 + \frac{15}{8}e^4 + \frac{7}{32}e^6 + \text{etc.} \\ &+ [2e + 3e^3 + \frac{6}{16}e^5 + \text{etc.}] \cos \varepsilon \\ &+ [\frac{3}{2}e^2 + \frac{2}{8}e^4 + \frac{1}{32}e^6 + \text{etc.}] \cos 2\varepsilon \\ &+ [e^3 + \frac{3}{16}e^5 + \text{etc.}] \cos 3\varepsilon \\ &+ [\frac{5}{8}e^4 + \frac{4}{32}e^6 + \text{etc.}] \cos 4\varepsilon \end{aligned}$$

Attributing to i proper values in equation (29) we find the expressions for $\cos \varepsilon$, $\cos 2\varepsilon$, $\cos 3\varepsilon$, etc. We then multiply these expressions by their appropriate factors and thus have the value of $\left(\frac{r}{a}\right)^{-2}$. Let

$$\left(\frac{r}{a}\right)^2 = \Sigma_{-\infty}^{+\infty} R_i^{(2)} \cos ig, \quad \left(\frac{r}{a}\right)^{-2} = \Sigma_{-\infty}^{+\infty} R_i^{(-2)} \cos ig.$$

The following are the values of $R_i^{(2)}$ and $R_i^{(-2)}$ to terms of the seventh order of e .

$$R_0^{(2)} = 1 + \frac{3}{2}e^2$$

$$R_1^{(2)} = -2e + \frac{1}{4}e^3 - \frac{1}{96}e^5 + \frac{1}{4608}e^7$$

$$R_2^{(2)} = -\frac{1}{2}e^2 + \frac{1}{6}e^4 - \frac{1}{48}e^6$$

$$R_3^{(2)} = -\frac{1}{4}e^3 + \frac{9}{64}e^5 - \frac{81}{2560}e^7$$

$$R_4^{(2)} = -\frac{1}{6}e^4 + \frac{2}{15}e^6$$

$$R_5^{(2)} = -\frac{25}{192}e^5 + \frac{625}{4608}e^7$$

$$R_6^{(2)} = -\frac{9}{80}e^6$$

$$R_7^{(2)} = -\frac{2401}{23040}e^7.$$

$$R_0^{(-2)} = \frac{1}{\sqrt{1-e^2}} = 1 + e^2 + \frac{3}{4}e^4 + \frac{15}{8}e^6 + \text{etc.}$$

$$R_1^{(-2)} = 2e + \frac{3}{4}e^3 + \frac{65}{96}e^5 + \frac{2675}{4608}e^7$$

$$R_2^{(-2)} = \frac{5}{2}e^2 + \frac{1}{3}e^4 + \frac{21}{32}e^6$$

$$R_3^{(-2)} = \frac{13}{4}e^3 - \frac{25}{64}e^5 + \frac{393}{512}e^7$$

$$R_4^{(-2)} = \frac{103}{24}e^4 - \frac{387}{240}e^6$$

$$R_5^{(-2)} = \frac{1097}{192}e^5 - \frac{16621}{4608}e^7$$

$$R_6^{(-2)} = \frac{1223}{160}e^6$$

$$R_7^{(-2)} = \frac{47273}{46080}e^7.$$

See HANSEN'S *Fundamenta nova*, pp. 172, 173.

We add also the differential coefficients of $R_i^{(2)}$, $R_i^{(-2)}$, relative to e .

$$\frac{dR_0^{(2)}}{de} = 3e$$

$$\frac{dR_1^{(2)}}{de} = -2 + \frac{3}{4}e^2 - \frac{5}{96}e^4 + \frac{7}{4608}e^6 \mp \text{etc.}$$

$$\frac{dR_2^{(2)}}{de} = -e + \frac{2}{3}e^3 - \frac{1}{8}e^5 \pm \text{etc.}$$

$$\frac{dR_3^{(2)}}{de} = -\frac{3}{4}e^2 + \frac{45}{64}e^4 - \frac{567}{2560}e^6 \pm \text{etc.}$$

$$\frac{dR_4^{(2)}}{de} = -\frac{2}{3}e^3 + \frac{4}{5}e^5 \mp \text{etc.}$$

$$\frac{dR_5^{(2)}}{de} = -\frac{125}{192}e^4 + \frac{4375}{4608}e^6 \mp \text{etc.}$$

$$\frac{dR_6^{(2)}}{de} = -\frac{27}{40}e^5 \pm \text{etc.}$$

$$\frac{dR_7^{(2)}}{de} = -\frac{16807}{23040}e^6 \pm \text{etc.}$$

$$\text{etc.} = \text{etc.}$$

$$\frac{dR_0^{(-2)}}{de} = e + 3e^3 + \frac{45}{4}e^5 + \frac{105}{2}e^7$$

$$\frac{dR_1^{(-2)}}{de} = 2 + \frac{9}{4}e^2 + \frac{325}{96}e^4 + \frac{18725}{4608}e^6$$

$$\frac{dR_2^{(-2)}}{de} = 5e + \frac{4}{3}e^3 + \frac{63}{16}e^5$$

$$\frac{dR_3^{(-2)}}{de} = \frac{39}{4}e^2 - \frac{125}{64}e^4 + \frac{2751}{512}e^6$$

$$\frac{dR_4^{(-2)}}{de} = \frac{103}{6}e^3 - \frac{387}{40}e^5$$

$$\frac{dR_5^{(-2)}}{de} = \frac{5485}{192}e^4 - \frac{116347}{4608}e^6$$

$$\frac{dR_6^{(-2)}}{de} = \frac{3669}{80}e^5$$

$$\frac{dR_7^{(-2)}}{de} = \frac{330911}{4608}e^6$$

The value of $\frac{r^2}{a^2}$ found by integrating $d\left(\frac{r^2}{a^2}\right) = 2e \cdot \sin \epsilon \cdot dg$, is

$$\frac{r^2}{a^2} = 1 + \frac{3}{2}e^2 - \frac{4}{1}J_{\lambda}^{(1)} \cos g - \frac{4}{4}J_{2\lambda}^{(2)} \cos 2g - \frac{4}{9}J_{3\lambda}^{(3)} \cos 3g - \text{etc.}$$

In terms of the $R_i^{(2)}$ functions,

$$\frac{r^2}{a^2} = 1 + \frac{3}{2}e^2 - R_1^{(2)} \cos g - R_2^{(2)} \cos 2g - R_3^{(2)} \cos 3g - \text{etc.}$$

Again, since

$$\frac{df}{dg} = \frac{a^2}{r^2} \sqrt{1 - e^2},$$

we have

$$\frac{a^2}{r^2} = R_i^{(-2)} \cos ig = \frac{1}{\sqrt{1 - e^2}} \cdot \frac{df}{dg}.$$

Let

$$f = g + \sum_{+1}^{+\infty} C_i \sin ig;$$

then

$$\frac{df}{dg} = 1 + \sum_{+1}^{+\infty} i C_i \cos ig,$$

and hence

$$R_i^{(-2)} = \frac{i \cdot C_i}{\sqrt{1 - e^2}}.$$

The coefficients represented by C_i designate the coefficients of the equation of the centre.

Using the values of the C_i coefficients given by LE VERRIER in the *Annales de l'Observatoire Impérial de Paris*, Tome Premier, p. 203, we have

$$\begin{aligned}
 f - g = & \left[4 \left(\frac{e}{2} \right) - 2 \left(\frac{e}{2} \right)^3 + \frac{5}{8} \left(\frac{e}{2} \right)^5 + \frac{107}{36} \left(\frac{e}{2} \right)^7 + \frac{6217}{720} \left(\frac{e}{2} \right)^9 \right] \sin g \\
 & + \left[5 \left(\frac{e}{2} \right)^2 - \frac{22}{3} \left(\frac{e}{2} \right)^4 + \frac{17}{3} \left(\frac{e}{2} \right)^6 + \frac{86}{45} \left(\frac{e}{2} \right)^8 + \text{etc.} \right] \sin 2g \\
 & + \left[\frac{26}{3} \left(\frac{e}{2} \right)^3 - \frac{43}{2} \left(\frac{e}{2} \right)^5 + \frac{95}{4} \left(\frac{e}{2} \right)^7 - \frac{973}{120} \left(\frac{e}{2} \right)^9 + \text{etc.} \right] \sin 3g \\
 & + \left[\frac{103}{6} \left(\frac{e}{2} \right)^4 - \frac{902}{15} \left(\frac{e}{2} \right)^6 + \frac{4123}{45} \left(\frac{e}{2} \right)^8 - \text{etc.} \right] \sin 4g \\
 & + \left[\frac{1097}{30} \left(\frac{e}{2} \right)^5 - \frac{5957}{36} \left(\frac{e}{2} \right)^7 + \frac{164921}{504} \left(\frac{e}{2} \right)^9 \right] \sin 5g \\
 & + \left[\frac{1223}{15} \left(\frac{e}{2} \right)^6 - \frac{15826}{85} \left(\frac{e}{2} \right)^8 + \text{etc.} \right] \sin 6g \\
 & + \left[\frac{47273}{252} \left(\frac{e}{2} \right)^7 - \frac{1773271}{1440} \left(\frac{e}{2} \right)^9 \right] \sin 7g \\
 & + \left[\frac{556403}{1260} \left(\frac{e}{2} \right)^8 \right] \sin 8g \\
 & + \left[\frac{10661993}{10080} \left(\frac{e}{2} \right)^9 \right] \sin 9g
 \end{aligned}$$

Converting the coefficients into seconds of arc, and writing the logarithms of the numbers, we have for the equation of the centre,

$$\begin{aligned}
 f - g = & \\
 & + \left[5.9164851 \left(\frac{e}{2} \right) - 5.6154551 \left(\frac{e}{2} \right)^3 + 5.5362739 \left(\frac{e}{2} \right)^5 + 5.787506 \left(\frac{e}{2} \right)^7 + 6.25067 \left(\frac{e}{2} \right)^9 \right] \sin g \\
 & + \left[6.0133951 \left(\frac{e}{2} \right)^2 - 6.1797266 \left(\frac{e}{2} \right)^4 + 6.067753 \left(\frac{e}{2} \right)^6 + 5.59571 \left(\frac{e}{2} \right)^8 \right] \sin 2g \\
 & + \left[6.2522772 \left(\frac{e}{2} \right)^3 - 6.6468636 \left(\frac{e}{2} \right)^5 + 6.690089 \left(\frac{e}{2} \right)^7 - 6.22336 \left(\frac{e}{2} \right)^9 \right] \sin 3g \\
 & + \left[6.5491111 \left(\frac{e}{2} \right)^4 - 7.093540 \left(\frac{e}{2} \right)^6 + 7.27643 \left(\frac{e}{2} \right)^8 \right] \sin 4g \\
 & + \left[6.8775105 \left(\frac{e}{2} \right)^5 - 7.533150 \left(\frac{e}{2} \right)^7 + 7.82927 \left(\frac{e}{2} \right)^9 \right] \sin 5g \\
 & + \left[7.225760 \left(\frac{e}{2} \right)^6 - 7.96973 \left(\frac{e}{2} \right)^8 \right] \sin 6g \\
 & + \left[7.587638 \left(\frac{e}{2} \right)^7 - 8.40484 \left(\frac{e}{2} \right)^9 \right] \sin 7g \\
 & + \left[7.95944 \left(\frac{e}{2} \right)^8 \right] \sin 8g \\
 & + \left[8.33880 \left(\frac{e}{2} \right)^9 \right] \sin 9g
 \end{aligned}$$

CHAPTER III.

Development of the Perturbing Function and the Disturbing Forces.

By means of the formulæ given in the preceding chapter, the functions $\mu \cdot \left(\frac{a}{\Delta}\right)$, $\mu \cdot \alpha^2 \left(\frac{a}{\Delta}\right)^3$, etc., can be put in the desired form. The next step is to determine the complete expression for the perturbing function, and also the expressions for the disturbing forces.

If k^2 is taken as the measure of the mass of the Sun, and m the relation between the mass of the Sun and that of a planet, the mass of the planet is represented by mk^2 .

If x, y, z , be the rectangular coördinate of a body, those of the disturbing body being expressed by the same letters with accents, the perturbing function is given in the form

$$\Omega = \frac{m'}{1+m} \left[\frac{1}{\Delta} - \frac{xx' + yy' + zz'}{r'^3} \right]$$

Now

$$\begin{aligned} \Delta^2 &= (x' - x)^2 + (y' - y)^2 + (z' - z)^2, \\ &= r^2 + r'^2 - 2rr' \cdot H; \end{aligned}$$

hence

$$a \Omega = \frac{m'}{1+m} \left[\frac{a}{\Delta} - \frac{ar}{r'^3} \cdot H \right]$$

If $a \Omega$ is regarded as expressed in seconds of arc, and if we put

$$s = 206264''.8, \quad \mu = \frac{m'}{1+m} \cdot s, \quad \alpha = \frac{a'}{a}, \quad (H) = \frac{\mu}{\alpha^3} \cdot \left(\frac{a'}{r'}\right)^2 \cdot \left(\frac{r}{a}\right) \cdot H,$$

we have

$$a \Omega = \mu \cdot \left(\frac{a}{\Delta}\right) - (H).$$

Finding the expression for (H) first by the method of HANSEN, we let

$$h = \frac{\mu}{a^2} \cdot k \cdot \cos (\Pi - K), \quad h' = \frac{\mu}{a^2} \cdot \cos \phi \cdot \cos \phi' \cdot k_1 \cdot \cos (\Pi - K_1)$$

$$l = \frac{\mu}{a^2} \cdot \cos \phi \cdot k \cdot \sin (\Pi - K), \quad l' = \frac{\mu}{a^2} \cdot \cos \phi' \cdot k_1 \cdot \sin (\Pi - K_1),$$

and have, if we make use of the eccentric anomaly,

$$\begin{aligned} (H) = & h \cdot \cos \varepsilon \left(\frac{a'}{r'} \right)^2 \cdot \cos f' - eh \left(\frac{a'}{r'} \right)^2 \cdot \cos f' - l \cdot \sin \varepsilon \cdot \left(\frac{a'}{r'} \right)^2 \cdot \cos f' \\ & + l' \cdot \cos \varepsilon \left(\frac{a'}{r'} \right)^2 \cdot \frac{\sin f'}{\cos \varphi'} - el' \left(\frac{a'}{r'} \right)^2 \cdot \frac{\sin f'}{\cos \varphi'} + h' \cdot \sin \varepsilon \left(\frac{a'}{r'} \right)^2 \cdot \frac{\sin f'}{\cos \varphi'} \end{aligned}$$

Putting

$$\left(\frac{a'}{r'} \right)^2 \cos f' = \gamma'_1 \cdot \cos g' + \gamma'_2 \cdot \cos 2g' + \gamma'_3 \cdot \cos 3g' + \text{etc.}$$

$$\left(\frac{a'}{r'} \right)^2 \cdot \frac{\sin f'}{\cos \varphi'} = \delta'_1 \cdot \sin g' + \delta'_2 \cdot \sin 2g' + \delta'_3 \cdot \sin 3g' + \text{etc.}$$

we find

$$\begin{aligned} (H) = & \frac{1}{2} (h\gamma'_1 - h'\delta'_1) \cos (-g' - \varepsilon) + \frac{1}{2} (l\gamma'_1 - l'\delta'_1) \sin (-g' - \varepsilon) \\ & - eh\gamma'_1 \cos (-g' - \varepsilon) + el'\delta'_1 \sin (-g' - \varepsilon) \\ & + \frac{1}{2} (h\gamma'_1 + h'\delta'_1) \cos (-g' - \varepsilon) + \frac{1}{2} (l\gamma'_1 + l'\delta'_1) \sin (-g' - \varepsilon) \\ & + 2(h\gamma'_2 - h'\delta'_2) \cos (-2g' - \varepsilon) + 2(l\gamma'_2 - l'\delta'_2) \sin (-2g' - \varepsilon) \\ & - 4.eh\gamma'_2 \cos (-2g' - \varepsilon) + 4.el'\delta'_2 \sin (-2g' - \varepsilon) \\ & + 2(h\gamma'_2 + h'\delta'_2) \cos (-2g' - \varepsilon) + 2(l\gamma'_2 + l'\delta'_2) \sin (-2g' - \varepsilon) \\ & + \text{etc.} \quad \quad \quad + \text{etc.,} \end{aligned} \quad (1)$$

where

$$\begin{aligned} \delta'_1 &= J_{\lambda'}^{(0)} + J_{\lambda'}^{(2)}, & \gamma'_1 &= J_{\lambda'}^{(0)} - J_{\lambda'}^{(2)} \\ \delta'_2 &= \frac{1}{2} [J_{2\lambda'}^{(1)} + J_{2\lambda'}^{(3)}], & \gamma'_2 &= \frac{1}{2} [J_{2\lambda'}^{(1)} - J_{2\lambda'}^{(3)}] \\ &\text{etc.} & &\text{etc.} \end{aligned}$$

When the numerical value of (H) has been found from this equation we transform it into another in which both the angles involved are mean anomalies. For this purpose we compute the values of the J functions depending on the eccentricity, e , of the disturbed body just as has been done for the disturbing body. The values of the J functions can be checked by means of the values of $J_{h\lambda}^{(0)}$, $J_{h\lambda}^{(1)}$, given in ENGELMAN'S edition of the *Abhandlungen von Friedrich Wilhelm Bessel*, Erster Band, seite 103-109, or by equations (30)₂.

Thus by means of the equation

$$J_{h\lambda}^{(m+1)} + J_{h\lambda}^{(m-1)} = \frac{m}{h.\lambda} \cdot J_{h\lambda}^{(m)}$$

we are enabled to find $J_{h\lambda}^{(m)}$ if $J_{h\lambda}^{(0)}$, $J_{h\lambda}^{(1)}$ are known.

It must be noted that the argument of BESSEL'S table is $2.h\frac{e}{2}$, or $2.h\lambda$, or he . Thus if it is sought to find the value of $J_{2\lambda}^{(1)}$, we enter the table with 2.2λ or $2e$ as the argument.

When we need the functions for h from $h = -1$ to $h = 4$, we must find the values of $\frac{1}{4}J_{4\frac{e}{2}}^{(3)}$, $\frac{1}{3}J_{3\frac{e}{2}}^{(2)}$, $\frac{1}{2}J_{2\frac{e}{2}}^{(1)}$, $\frac{1}{1}J_{\frac{e}{2}}^{(0)}$, $-\frac{e}{2}$, and $-\frac{1}{1}J_{-\frac{e}{2}}^{(-2)}$.

The values of $\frac{1}{2} \cdot J_{2\frac{e}{2}}^{(1)}$ and $J_{\frac{e}{2}}^{(0)}$ we take from the table. To find $J_{4\frac{e}{2}}^{(3)}$ we have

$$\begin{aligned} J_{4\frac{e}{2}}^{(3)} &= -J_{4\frac{e}{2}}^{(1)} + \frac{2}{4.\frac{e}{2}} \cdot J_{4\frac{e}{2}}^{(2)} \\ &= -J_{4\frac{e}{2}}^{(1)} + \frac{2}{4.\frac{e}{2}} \left[-J_{4\frac{e}{2}}^{(0)} + \frac{1}{4.\frac{e}{2}} \cdot J_{4\frac{e}{2}}^{(1)} \right] \end{aligned}$$

For $J_{3\frac{e}{2}}^{(2)}$ we have

$$J_{3\frac{e}{2}}^{(2)} = -J_{3\frac{e}{2}}^{(0)} + \frac{1}{3.\frac{e}{2}} \cdot J_{3\frac{e}{2}}^{(1)}$$

And for $J_{\frac{e}{2}}^{(2)}$ we have

$$J_{\frac{e}{2}}^{(2)} = -J_{\frac{e}{2}}^{(0)} + \frac{1}{\frac{e}{2}} \cdot J_{\frac{e}{2}}^{(1)}$$

The expression for (H) can be put in a form in which both the angles are mean anomalies. Thus, resuming the expression for (H) ,

$$\begin{aligned} (H) = & h \cdot \cos \varepsilon \left(\frac{a'}{r'}\right)^2 \cos f' - eh \left(\frac{a'}{r'}\right)^2 \cos f' - l \cdot \sin \varepsilon \left(\frac{a'}{r'}\right)^2 \cdot \cos f' \\ & + l' \cdot \cos \varepsilon \left(\frac{a'}{r'}\right)^2 \cdot \frac{\sin f'}{\cos \varphi'} - el' \left(\frac{a'}{r'}\right)^2 \cdot \frac{\sin f'}{\cos \varphi'} + h' \cdot \sin \varepsilon \cdot \left(\frac{a'}{r'}\right)^2 \cdot \frac{\sin f'}{\cos \varphi'}, \end{aligned}$$

in which

$$h = \frac{\mu}{a^2} \cdot k \cdot \cos (\Pi - K)$$

$$h' = \frac{\mu}{a^2} \cdot \cos \phi \cdot \cos \phi' \cdot k_1 \cdot \cos (\Pi - K_1) = \frac{1}{2}u \cdot \frac{v \cos V}{a^3}$$

$$l = \frac{\mu}{a^2} \cdot \cos \phi, \quad k \cdot \sin (\Pi - K) = \frac{1}{2}u \cdot \frac{v \sin V}{a^3}$$

$$l' = \frac{\mu}{a^2} \cdot \cos \phi', \quad k_1 \cdot \sin (\Pi - K_1) = \frac{1}{2}u \cdot \frac{p \cos P}{a^3},$$

we find the expressions for $\left(\frac{a'}{r'}\right)^2 \cos f'$, $\left(\frac{a'}{r'}\right)^2 \frac{\sin f'}{\cos \varphi'}$, as follows. We put as before

$$\left(\frac{a'}{r'}\right)^2 \cos f' = \gamma'_1 \cos g' + \gamma'_2 \cos 2g' + \gamma'_3 \cos 3g' + \text{etc.}$$

$$\left(\frac{a'}{r'}\right)^2 \frac{\sin f'}{\cos \varphi'} = \delta'_1 \sin g' + \delta'_2 \sin 2g' + \delta'_3 \sin 3g' + \text{etc.}$$

If we differentiate $\frac{r'}{a'} \cos f'$ relative to g' we have

$$\frac{d\left(\frac{r'}{a'} \cos f'\right)}{dg'} = \frac{\cos f'}{a'} \cdot \frac{dr'}{dg'} - \frac{r'}{a'} \cdot \sin f' \cdot \frac{df'}{dg'} = -\frac{\sin f'}{\cos \varphi'},$$

since

$$\frac{dr'}{dg'} = \frac{a'e' \sin f'}{\cos \varphi'}, \quad \frac{df'}{dg'} = \frac{a'^2}{r'^2} \cdot \cos \phi;$$

and hence

$$\frac{d^2\left(\frac{r'}{a'} \cos f'\right)}{dg'^2} = -\frac{a'^2}{r'^2} \cdot \cos f'.$$

Similarly, in the case of $\frac{r'}{a'} \frac{\sin f'}{\cos \varphi'}$, we have

$$\frac{d^2}{dg'^2} \left(\frac{r'}{a'} \frac{\sin f'}{\cos \varphi'} \right) = - \frac{a'^2}{r'^2} \cdot \frac{\sin f'}{\cos \varphi'}.$$

But $\frac{r'}{a'} \cos f' = \cos \varepsilon' - e'$, and $\frac{r'}{a'} \frac{\sin f'}{\cos \varphi'} = \sin \varepsilon'$.

Hence

$$\begin{aligned} - \frac{d^2 \left(\frac{r'}{a'} \cos f' \right)}{dg'^2} &= \frac{a'^2}{r'^2} \cos f' = - \frac{d^2 \cdot \cos \varepsilon'}{dg'^2}, \\ - \frac{d^2 \left(\frac{r'}{a'} \frac{\sin f'}{\cos \varphi'} \right)}{dg'^2} &= \frac{a'^2}{r'^2} \cdot \frac{\sin f'}{\cos \varphi'} = - \frac{d^2 \cdot \sin \varepsilon'}{dg'^2}. \end{aligned}$$

Now

$$\begin{aligned} \cos \varepsilon' &= -\lambda' + \left[J_{\lambda'}^{(0)} - J_{\lambda'}^{(2)} \right] \cos g' + \frac{1}{2} \left[J_{2\lambda'}^{(1)} - J_{2\lambda'}^{(3)} \right] \cos 2g' + \text{etc.} \\ \sin \varepsilon' &= \left[J_{\lambda'}^{(0)} + J_{\lambda'}^{(2)} \right] \sin g' + \frac{1}{2} \left[J_{2\lambda'}^{(1)} + J_{2\lambda'}^{(3)} \right] \sin 2g' + \text{etc.} \end{aligned}$$

From the values of $\cos \varepsilon'$ and $\sin \varepsilon'$ we have

$$\begin{aligned} \frac{a'^2}{r'^2} \cos f' &= \left[J_{\lambda'}^{(0)} - J_{\lambda'}^{(2)} \right] \cos g' + 2 \left[J_{2\lambda'}^{(1)} - J_{2\lambda'}^{(3)} \right] \cos 2g' + 3 \left[J_{3\lambda'}^{(2)} - J_{3\lambda'}^{(4)} \right] \cos 3g' + \text{etc.} \\ \frac{a'^2}{r'^2} \frac{\sin f'}{\cos \varphi'} &= \left[J_{\lambda'}^{(0)} + J_{\lambda'}^{(2)} \right] \sin g' + 2 \left[J_{2\lambda'}^{(1)} + J_{2\lambda'}^{(3)} \right] \sin 2g' + 3 \left[J_{3\lambda'}^{(2)} + J_{3\lambda'}^{(4)} \right] \sin 3g' + \text{etc.} \end{aligned}$$

We now assume

$$\begin{aligned} \gamma_i &= \frac{1}{i} \left[J_{i\lambda}^{(i-1)} - J_{i\lambda}^{(i+1)} \right], & \delta_i &= \frac{1}{i} \left[J_{i\lambda}^{(i-1)} + J_{i\lambda}^{(i+1)} \right] \\ \gamma'_{i'} &= \frac{1}{i'} \left[J_{i'\lambda'}^{(i'-1)} - J_{i'\lambda'}^{(i'+1)} \right], & \delta'_{i'} &= \frac{1}{i'} \left[J_{i'\lambda'}^{(i'-1)} + J_{i'\lambda'}^{(i'+1)} \right]. \end{aligned}$$

Comparing these expressions for $\gamma'_{i'}$, $\delta'_{i'}$, with those found in the expression for $\frac{a'^2}{r'^2} \cdot \frac{\sin f'}{\cos \varphi'}$ given above, we see that the relation between them is i'^2 .

The expressions for $\cos \varepsilon$, $\sin \varepsilon$, are the same as those of $\cos \varepsilon'$, $\sin \varepsilon'$, if we omit the accents.

Hence if we perform the operations indicated in the expression for (H) , we have

$$\begin{aligned} (H) &= \frac{\mu}{a^2} \cdot \left(\frac{a'}{r'}\right)^2 \cdot \frac{r}{a} \cdot H \\ &= \frac{1}{2} i'^2 [h\gamma\gamma'_{i'} \pm h'\delta_i\delta'_{i'}] \cos(\pm ig - i'g') - \frac{1}{2} i'^2 [l\delta_i\gamma'_{i'} \pm l'\gamma_i\delta'_{i'}] \sin(\pm ig - i'g') \quad (2) \end{aligned}$$

i and i' having all positive values.

Attributing to i and i' particular values, we find, noting that $\delta_0 = 0$, and $\delta'_0 = 0'$,

$$\begin{aligned} (H) &= \frac{1}{2} [h.\gamma_1\gamma'_1 + h'\delta_1\delta'_1] \cos(g - g') - \frac{1}{2} [l\delta_1\gamma'_1 + l'\gamma_1\delta'_1] \sin(g - g') \\ &\quad + \frac{1}{2} [h.\gamma_1\gamma'_1 - h'\delta_1\delta'_1] \cos(-g - g') - \frac{1}{2} [l\delta_1\gamma'_1 - l'\gamma_1\delta'_1] \sin(-g - g') \\ &\quad + \frac{1}{2} h.\gamma_0\gamma'_1 \cos(-g') - \frac{1}{2} l'\gamma_0\delta'_1 \sin(-g') \\ &\quad + 2[h.\gamma_1\gamma'_2 + h'\delta_1\delta'_2] \cos(g - 2g') - 2[l\delta_1\gamma'_2 + l'\gamma_1\delta'_2] \sin(g - 2g') \\ &\quad + 2[h.\gamma_1\gamma'_2 - h'\delta_1\delta'_2] \cos(-g - 2g') - 2[l\delta_1\gamma'_2 - l'\gamma_1\delta'_2] \sin(-g - 2g') \\ &\quad + 2h.\gamma_0\gamma'_2 \cos(-2g') - 2l'\gamma_0\delta'_2 \sin(-2g') \\ &\quad + \frac{3}{2} [h.\gamma_1\gamma'_3 + h'\delta_1\delta'_3] \cos(g - 3g') - \frac{3}{2} [l\delta_1\gamma'_3 + l'\gamma_1\delta'_3] \sin(g - 3g') \\ &\quad + \text{etc.} \quad \quad \quad - \text{etc.} \\ &\quad + \frac{1}{2} [h.\gamma_2\gamma'_1 + h'\delta_2\delta'_1] \cos(2g - g') - \frac{1}{2} [l\delta_2\gamma'_1 + l'\gamma_2\delta'_1] \sin(2g - g') \\ &\quad + \frac{1}{2} [h.\gamma_2\gamma'_1 - h'\delta_2\delta'_1] \cos(-2g - g') - \frac{1}{2} [l\delta_2\gamma'_1 - l'\gamma_2\delta'_1] \sin(-2g - g') \\ &\quad + \text{etc.} \quad \quad \quad - \text{etc.} \end{aligned}$$

The numerical value of (H) given by (1) must first be transformed into a series in which both the angles involved are mean anomalies before it can be compared with the value given by the equation just found.

If we find the value of (H) from the preceding equation, it can be checked by means of the tables in BESSEL'S *Werke*.

The expression for $\mu \left(\frac{a}{d}\right)$ is known; and with the expression for (H) just given, we obtain the value of

$$a \cdot \Omega = \mu \left(\frac{a}{d}\right) - (H).$$

The next step is to obtain expressions for the disturbing forces.

Let v the angle between the positive axis of X and the radius-vector measured in the plane of the disturbed body, here called the plane of XY . The differential coefficient of the perturbing function Ω relative to the ordinate Z perpendicular to this plane is found by differentiating Ω relative to z and afterwards putting $z = 0$.

Thus from

$$\begin{aligned}\Omega &= \frac{m'}{1+m} \left[\frac{1}{\Delta} - \frac{rr'}{r'^3} \cdot H \right], \\ &= \frac{m'}{1+m} \left[\frac{1}{\Delta} - \frac{xx' + yy' + zz'}{r'^3} \right], \\ \Delta^2 &= (x-x')^2 + (y-y')^2 + (z-z')^2, \\ &= r^2 + r'^2 - 2rr' H,\end{aligned}$$

we find

$$\begin{aligned}\frac{d\Omega}{dv} &= \frac{m'}{1+m} \left[-\frac{1}{\Delta^2} \cdot \frac{d\Delta}{dv} - \frac{r}{r'^2} \cdot \frac{dH}{dv} \right], \\ \frac{d\Omega}{dr} &= \frac{m'}{1+m} \left[-\frac{1}{\Delta^3} \left(\frac{r-r'H}{\Delta} \right) - \frac{H}{r'^2} \right], \\ d\Omega &= \frac{m'}{1+m} \left[-\frac{1}{\Delta^2} \cdot d\Delta - z' \cdot \frac{dz}{r'^3} \right], \\ \Delta \frac{d\Delta}{dv} &= -rr' \frac{dH}{dv}, \quad \Delta \frac{d\Delta}{dr} = r-r'H, \quad \frac{d\Delta}{dz} = -\frac{z'}{\Delta}.\end{aligned}$$

Hence

$$\begin{aligned}\frac{d\Omega}{dv} &= -\frac{m'}{1+m} \left[\frac{1}{\Delta^3} - \frac{1}{r'^3} \right] rr' H \\ r \frac{d\Omega}{dr} &= \frac{m'}{1+m} \left[\frac{1}{\Delta^3} - \frac{1}{r'^3} \right] rr' H - \frac{m'}{1+m} \cdot \frac{r^2}{\Delta^3} \\ \frac{d\Omega}{dZ} &= -\frac{m'}{1+m} \left[\frac{1}{\Delta^3} - \frac{1}{r'^3} \right] \sin I \cdot r' \sin (f' + \Pi')\end{aligned}$$

where

$$\begin{aligned}H &= \sin (f + \Pi) \cos (f' + \Pi') - \cos I \cos (f + \Pi) \sin (f' + \Pi') \\ z' &= -r' \cdot \sin I \sin (f' + \Pi').\end{aligned}$$

As before the origin of angles here is at the ascending node of the plane of the disturbed body on the plane of the disturbing body, and the plane of reference is that of the disturbed body.

If we differentiate the expressions for $r \frac{d\Omega}{dr}$, $\frac{d\Omega}{dZ}$, we find

$$\begin{aligned} r^2 \frac{d^2\Omega}{dr^2} + r \frac{d\Omega}{dr} &= \frac{m'}{1+m} \cdot \frac{3}{\Delta^5} (r^2 - rr'H)^2 \\ &\quad + \frac{m'}{1+m} \left(\frac{1}{\Delta^3} - \frac{1}{r'^3} \right) rr'H - 2 \frac{m'}{1+m} \cdot \frac{r^2}{\Delta^3} \\ r \frac{d^2\Omega}{dr dZ} &= \frac{m'}{1+m} \cdot \frac{3}{\Delta^5} (r^2 - rr'H) \sin I r' \sin (f' + \Pi') \\ \frac{d^2\Omega}{dZ^2} &= \frac{m'}{1+m} \cdot \frac{3}{\Delta^5} \sin^2 I r'^2 \sin^2 (f' + \Pi') - \frac{m'}{1+m} \cdot \frac{1}{\Delta^3} \\ \frac{d\Omega}{dZ'} &= \frac{m'}{1+m} \left(\frac{1}{\Delta^3} - \frac{1}{r'^3} \right) \sin I \cdot r \sin (f + \Pi) \\ r \frac{d^2\Omega}{dr dZ'} &= - \frac{m'}{1+m} \cdot \frac{3}{\Delta^5} (r^2 - rr'H) \sin I \cdot r \sin (f + \Pi) + \frac{d\Omega}{dZ'} \\ \frac{d^2\Omega}{dZ dZ'} &= - \frac{m'}{1+m} \cdot \frac{3}{\Delta^5} \sin^2 I \cdot rr' \sin (f + \Pi) \sin (f' + \Pi') + \frac{m'}{1+m} \left(\frac{1}{\Delta^3} - \frac{1}{r'^3} \right) \cos I \end{aligned}$$

To eliminate H from some of these expressions we find from

$$\Delta^2 = r^2 + r'^2 - 2rr' \cos I,$$

that

$$\frac{rr'H}{\Delta^3} = \frac{r'^2 - r^2}{2\Delta^3} - \frac{1}{2\Delta}$$

The expression for $r \frac{d\Omega}{dr}$ then becomes

$$r \frac{d\Omega}{dr} = \frac{m'}{1+m} \left[\frac{r'^2 - r^2}{2\Delta^3} - \frac{1}{2\Delta} - \frac{r}{r'^2} H \right]$$

From the value of Δ^2 we have, further,

$$\frac{r^2 - rr'H}{\Delta^5} = - \frac{r'^2 - r^2}{2\Delta^5} + \frac{1}{2\Delta^3},$$

and hence

$$r \frac{d^2 \Omega}{dr dZ} = -\frac{3}{2} \frac{m'}{1+m} \left[\frac{r'^2 - r^2}{\Delta^5} - \frac{1}{\Delta^3} \right] \sin I \cdot r' \sin (f' + \Pi')$$

$$r \frac{d^2 \Omega}{dr dZ'} = \frac{3}{2} \frac{m'}{1+m} \left[\frac{r'^2 - r^2}{\Delta^5} - \frac{1}{\Delta^3} \right] \sin I \cdot r \sin (f + \Pi) + \frac{d\Omega}{dZ'},$$

the latter of which, by means of the expression for $\frac{d\Omega}{dZ'}$, becomes

$$r \frac{d^2 \Omega}{dr dZ'} = \frac{3}{2} \frac{m'}{1+m} \left[\frac{r'^2 - r^2}{\Delta^5} - \frac{1}{3\Delta^3} \right] \sin I r \sin (f + \Pi) - \frac{m'}{1+m} \sin I \frac{r}{r'^3} \sin (f + \Pi)$$

The expression for Δ^2 also gives

$$\frac{(r^2 - rr'H)^2}{\Delta^6} = \frac{(r'^2 - r^2)^2}{4\Delta^6} - \frac{r'^2 - r^2}{2\Delta^3} + \frac{1}{4\Delta},$$

by means of which we find

$$r^2 \frac{d^3 \Omega}{dr^2} + r \frac{d\Omega}{dr} = \frac{m'}{1+m} \left[\frac{3(r'^2 - r^2)^2}{4\Delta^6} - \frac{r'^2}{\Delta^3} + \frac{1}{4\Delta} \right] - \frac{m'}{1+m} \cdot \frac{r}{r'^2} \cdot H.$$

If we put, for brevity,

$$(I) = \frac{\mu}{a^2} \cdot \sin I \left(\frac{a'}{r'} \right)^2 \sin (f' + \Pi')$$

$$(I)' = \frac{\mu}{a^2} \cdot \sin I \left(\frac{a'}{r'} \right)^3 \cdot \left(\frac{r}{a} \right) \sin (f + \Pi)$$

$$(I)'' = \frac{\mu}{a^2} \cdot \cos I \left(\frac{a'}{r'} \right)^3$$

the expressions which have been given for the forces, together with the perturbing function, are

$$a\Omega = \mu \left(\frac{a}{\Delta} \right) - (H)$$

$$ar \left(\frac{d\Omega}{dr} \right) = \frac{1}{2} \mu a^2 \left(\frac{a}{\Delta} \right)^3 \left[\frac{r'^2}{a'^2} - \frac{1}{a^2} \cdot \frac{r^2}{a^2} \right] - \frac{1}{2} \mu \left(\frac{a}{\Delta} \right) - (H)$$

$$a^2 \left(\frac{d\Omega}{dZ} \right) = -\mu a^2 \left(\frac{a}{\Delta} \right)^3 \cdot \frac{\sin I}{a} \cdot \frac{r'}{a'} \sin (f' + \Pi') + (I)$$

$$ar^2 \left(\frac{d^2\Omega}{dr^2} \right) + ar \left(\frac{d\Omega}{dr} \right) = \frac{3}{4} \mu a^4 \left(\frac{a}{\Delta} \right)^5 \left[\frac{r'^2}{a'^2} - \frac{1}{a^2} \cdot \frac{r^2}{a^2} \right]^2 - \mu a^2 \left(\frac{a}{\Delta} \right)^3 \cdot \frac{r'^2}{a'^2} + \frac{1}{4} \mu \left(\frac{a}{\Delta} \right) - (H)$$

$$a^2 r \left(\frac{d^2\Omega}{dr dZ} \right) = -\frac{3}{2} \mu a^4 \left(\frac{a}{\Delta} \right)^5 \left[\frac{r'^2}{a'^2} - \frac{1}{a^2} \cdot \frac{r^2}{a^2} \right] \frac{\sin I}{a} \cdot \frac{r'}{a'} \sin (f' + \Pi')$$

$$+ \frac{3}{2} \mu a^2 \left(\frac{a}{\Delta} \right)^3 \frac{\sin I}{a} \cdot \frac{r'}{a'} \sin (f' + \Pi')$$

$$a^3 \left(\frac{d^3\Omega}{dZ^3} \right) = 3\mu a^4 \left(\frac{a}{\Delta} \right)^5 \cdot \frac{\sin^2 I}{a^2} \cdot \frac{r'^2}{a'^2} \cdot \sin^2 (f' + \Pi') - \mu \left(\frac{a}{\Delta} \right)^3$$

$$aa' \left(\frac{d\Omega}{dZ'} \right) = \mu a^2 \left(\frac{a}{\Delta} \right)^3 \cdot \frac{\sin I}{a} \cdot \frac{r}{a} \sin (f + \Pi) - (I)'$$

$$aa' r \left(\frac{d^2\Omega}{dr dZ'} \right) = \frac{3}{2} \mu a^4 \left(\frac{a}{\Delta} \right)^5 \left[\frac{r'^2}{a'^2} - \frac{1}{a^2} \cdot \frac{r^2}{a^2} \right] \frac{\sin I}{a} \cdot \frac{r}{a} \sin (f + \Pi)$$

$$- \frac{1}{2} \mu a^2 \left(\frac{a}{\Delta} \right)^3 \cdot \frac{\sin I}{a} \cdot \frac{r}{a} \sin (f + \Pi) - (I)'$$

$$a^2 a' \left(\frac{d^2\Omega}{dZ dZ'} \right) = -3\mu a^4 \left(\frac{a}{\Delta} \right)^5 \cdot \frac{\sin^2 I}{a^2} \cdot \frac{r'}{a'} \sin (f' + \Pi') \cdot \frac{r}{a} \sin (f + \Pi) + \mu a^2 \left(\frac{a}{\Delta} \right)^3 \frac{\cos I}{a} - (I)''$$

The form given to these expressions is the one best adapted to numerical computations; and the equations are readily derived from the preceding in which the magnitudes occur in linear form.

Thus from

$$r \frac{d\Omega}{dr} = \frac{m'}{1+m} \left[\frac{r'^2 - r^2}{2\Delta^3} - \frac{1}{2\Delta} - \frac{r}{r'^2} H \right]$$

we have

$$\begin{aligned}
 ar \frac{d\Omega}{dr} &= \frac{\mu}{2} \left[\frac{a^3}{a'^2} \cdot \frac{r'^2}{J^2} - \frac{a^3}{a'^2} \cdot \frac{r'^2}{J^2} \right] - \frac{\mu}{2} \cdot \frac{a}{J} - \frac{\mu}{a'^2} \cdot \frac{a'^2}{r'^2} \cdot a^2 \cdot \frac{r}{a} \cdot H \\
 &= \frac{\mu}{2} \left(\frac{a}{J} \right)^3 \left[\alpha^2 \left(\frac{r'}{a'} \right)^2 - \left(\frac{r}{a} \right)^2 \right] - \frac{\mu}{2} \left(\frac{a}{J} \right) - \frac{\mu}{a^2} \left(\frac{a'}{r'} \right)^2 \cdot \frac{r}{a} \cdot H \\
 &= \frac{\mu}{2} \left(\frac{a}{J} \right)^3 \left[\alpha^2 \left(\frac{r'}{a'} \right)^2 - \left(\frac{r}{a} \right)^2 \right] - \frac{\mu}{2} \left(\frac{a}{J} \right) - (H),
 \end{aligned}$$

where, as before,

$$\mu = \frac{m'}{1 + m} \cdot s, \quad (H) = \frac{\mu}{a^2} \cdot \left(\frac{a'}{r'} \right)^2 \cdot \frac{r}{a} \cdot H, \quad \alpha = \frac{a'}{a}$$

In a similar manner all the other expressions for the forces have been derived.

When we compute only perturbations of the first order with respect to the mass we need the perturbing function

$$a\Omega = \mu \left(\frac{a}{J} \right) - H$$

and the forces

$$\begin{aligned}
 ar \frac{d\Omega}{dr} &= \frac{1}{2} \mu \alpha^2 \left(\frac{a}{J} \right)^3 \left[\frac{r'^2}{a'^2} - \frac{1}{a^2} \cdot \frac{r^2}{a^2} \right] - \frac{1}{2} \mu \left(\frac{a}{J} \right) - (H) \\
 a^2 \frac{d\Omega}{dZ} &= -\mu \alpha^2 \left(\frac{a}{J} \right)^3 \cdot \frac{\sin I}{\alpha} \cdot \frac{r'}{a'} \sin (f' + \Pi') + (I).
 \end{aligned}$$

The other forces are only needed when we take into the account terms of the second order also with respect to the mass.

An inspection of the expressions for the forces shows that besides the functions

$$\mu \left(\frac{a}{J} \right), \mu \alpha^2 \left(\frac{a}{J} \right)^3, \mu \alpha^4 \left(\frac{a}{J} \right)^5$$

we need expressions for the magnitudes

$$\begin{aligned}
 &\left(\frac{r'}{a'} \right)^2, \quad \frac{1}{a'^2} \cdot \frac{r^2}{a^2}, \quad \frac{\sin I}{\alpha} \cdot \frac{r'}{a'} \sin (f' + \Pi'), \quad \frac{\sin I}{\alpha} \cdot \frac{r}{a} \sin (f + \Pi), \\
 &(H), (I), (I)', (I)''.
 \end{aligned}$$

When these are known we multiply the function $\mu\alpha^2\left(\frac{a}{a'}\right)^3$ by

$$\left[\left(\frac{r'}{a'}\right)^2 - \frac{1}{a^2} \cdot \frac{r'^2}{a^2}\right], \quad \frac{\sin I}{a} \cdot \frac{r'}{a'} \sin(f' + \Pi'), \quad \frac{\sin I}{a} \frac{r}{a} \sin(f + \Pi),$$

$$\left(\frac{r'}{a'}\right)^2, \quad \frac{\cos I}{a};$$

the function $\mu\alpha\left(\frac{a}{a'}\right)^5$ by

$$\frac{3}{4} \left[\frac{r'^2}{a'^2} - \frac{1}{a^2} \frac{r'^2}{a^2} \right]^2, \quad \frac{3}{2} \frac{\sin I}{a} \frac{r'}{a'} \sin(f' + \Pi') \left[\frac{r'^2}{a'^2} - \frac{1}{a^2} \frac{r'^2}{a^2} \right],$$

$$3 \frac{\sin^2 I}{a^2} \cdot \frac{r'^2}{a'^2} \sin^2(f' + \Pi'), \quad \frac{3}{2} \frac{\sin I}{a} \frac{r}{a} \sin(f + \Pi) \left[\frac{r'^2}{a'^2} - \frac{1}{a^2} \frac{r'^2}{a^2} \right]$$

$$3 \frac{\sin^2 I}{a^2} \frac{r}{a} \sin(f + \Pi) \frac{r'}{a'} \sin(f' + \Pi').$$

We will now find the expressions for (I) , $(I)'$, $(I)''$, and for the various factors just given, that are the most convenient for numerical computation.

We have

$$(I) = \frac{\mu}{a^2} \sin I \left(\frac{a'}{r'}\right)^2 \sin(f' + \Pi').$$

Putting, for brevity,

$$b = -\frac{\mu}{a^2} \cos \phi' \sin \tilde{I} \cos \Pi'$$

$$b' = \frac{\mu}{a^2} \sin I \sin \Pi',$$

and noting that

$$\left(\frac{a'}{r'}\right)^2 \frac{\sin f'}{\cos \phi'} = [J_{\lambda'}^{(0)} + J_{\lambda'}^{(2)}] \sin g' + 2[J_{2\lambda'}^{(1)} + J_{2\lambda'}^{(3)}] \sin 2g' + \text{etc.}$$

$$\left(\frac{a'}{r'}\right)^2 \cos f' = [J_{\lambda'}^{(0)} - J_{\lambda'}^{(2)}] \cos g' + 2[J_{2\lambda'}^{(1)} - J_{2\lambda'}^{(3)}] \cos 2g' + \text{etc.}$$

we have

$$\left. \begin{aligned} (I) = & b \left[J_{\lambda'}^{(0)} + J_{\lambda'}^{(2)} \right] \sin(-g') + b' \left[J_{\lambda'}^{(0)} - J_{\lambda'}^{(2)} \right] \cos(-g') \\ & + 2b \left[J_{2\lambda'}^{(1)} + J_{2\lambda'}^{(3)} \right] \sin(-2g') + 2b' \left[J_{2\lambda'}^{(1)} - J_{2\lambda'}^{(3)} \right] \cos(-2g') \\ & + 3b \left[J_{3\lambda'}^{(2)} + J_{3\lambda'}^{(4)} \right] \sin(-3g') + 3b' \left[J_{3\lambda'}^{(2)} - J_{3\lambda'}^{(4)} \right] \cos(-3g') \\ & + \text{etc.} \qquad \qquad \qquad + \text{etc.} \end{aligned} \right\} \quad (3)$$

The value of $(I)'$ is found from

$$(I)' = \frac{\mu}{a^2} \sin I \left(\frac{a'}{r'} \right)^3 \cdot \frac{r}{a} \sin(f + \Pi).$$

From

$$\frac{r'}{a'} = 1 - e' \cos \varepsilon',$$

we find

$$\left(\frac{a'}{r'} \right)^3 = (1 - e' \cos \varepsilon')^{-3}.$$

Expanding,

$$\begin{aligned} \left(\frac{a'}{r'} \right)^3 = & \frac{1}{\cos^3 \varphi'} + (3e' + \frac{27}{8}e'^3 + \text{etc.}) \cos g' \\ & + (\frac{9}{2}e'^2 + \frac{7}{2}e'^4 + \text{etc.}) \cos 2g' \\ & + \frac{53}{8}e'^3 \cos 3g' + \frac{231}{24}e'^4 \cos 4g' + \text{etc.}; \end{aligned}$$

which, for brevity, we write,

$$\left(\frac{a'}{r'} \right)^3 = \rho_0 + 2\rho_1 \cos g' + 2\rho_2 \cos 2g' + 2\rho_3 \cos 3g' + \text{etc.}$$

But

$$\begin{aligned} \frac{r}{a} \cdot \frac{\sin f}{\cos \varphi} = & \left[J_{\lambda}^{(0)} + J_{\lambda}^{(2)} \right] \sin g + \frac{1}{2} \left[J_{2\lambda}^{(1)} + J_{2\lambda}^{(3)} \right] \sin 2g + \text{etc.} \\ \frac{r}{a} \cdot \cos f = & -\frac{3}{2}e + \left[J_{\lambda}^{(0)} - J_{\lambda}^{(2)} \right] \cos g + \frac{1}{2} \left[J_{2\lambda}^{(1)} - J_{2\lambda}^{(3)} \right] \cos 2g + \text{etc.} \end{aligned}$$

Putting

$$\begin{aligned}
 l &= \frac{\mu}{a^3} \cdot \cos \phi \sin I \cos \Pi, & l_1 &= \frac{\mu}{a^3} \cdot \sin I \sin \Pi, \\
 \gamma_1 &= J_\lambda^{(0)} - J_\lambda^{(2)} & \delta_1 &= J_\lambda^{(0)} + J_\lambda^{(2)} \\
 \gamma_2 &= \frac{1}{2} [J_{2\lambda}^{(1)} - J_{2\lambda}^{(3)}] & \delta_2 &= \frac{1}{2} [J_{2\lambda}^{(0)} + J_{2\lambda}^{(2)}] \\
 &\text{etc.} & &\text{etc.,}
 \end{aligned}$$

we have

$$\begin{aligned}
 (I)' = & \left. \begin{aligned}
 & - \frac{3}{2} l_1 e \cdot \rho_0 \\
 & + l \cdot \rho_0 \cdot \delta_1 \sin g & + l_1 \cdot \rho_0 \cdot \gamma_1 \cos g \\
 & + l \cdot \rho_1 \cdot \delta_1 \sin (g - g') & + l_1 \cdot \rho_1 \cdot \gamma_1 \cos (g - g') \\
 & - l \cdot \rho_1 \cdot \delta_1 \sin (-g - g') & + l_1 \cdot \rho_1 \cdot \gamma_1 \cos (-g - g') \\
 & & - 2 l_1 e \rho_1 \cos (g - g') \\
 & + l \cdot \rho_2 \cdot \delta_1 \sin (g - 2g') & + l_1 \cdot \rho_2 \cdot \gamma_1 \cos (g - 2g') \\
 & - l \cdot \rho_2 \cdot \delta_1 \sin (-g - 2g') & + l_1 \cdot \rho_2 \cdot \gamma_1 \cos (-g - 2g') \\
 & & - 2 l_1 e \cdot \rho_2 \cos (g - 2g') \\
 & \pm \text{etc.} & \pm \text{etc.}
 \end{aligned} \right\} \quad (4)
 \end{aligned}$$

For $(I)''$ we have the expression

$$(I)'' = \frac{\mu}{a^3} \cdot \cos I \left(\frac{a'}{r'} \right)^3.$$

Putting

$$l_3 = 2 \cdot \frac{\mu}{a^3} \cos I, \quad \text{and using the } \rho_i \text{ coefficients as for } (I)',$$

we have

$$(I)'' = \frac{l_3 \cdot \rho_0}{2} + l_3 \cdot \rho_1 \cos (-g') + l_3 \cdot \rho_2 \cos (-2g') + \text{etc.} \quad (5)$$

To obtain an expression for the factor $\left[\left(\frac{r'}{a'} \right)^2 - \frac{1}{a^2} \frac{r^2}{a^2} \right]$ it is only necessary to have that for $\left(\frac{r}{a} \right)^2$.

In terms of the eccentric anomaly we have, at once,

$$\begin{aligned}\left(\frac{r}{a}\right)^2 &= 1 - 2e \cos \varepsilon + e^2 \cos^2 \varepsilon \\ &= 1 + \frac{1}{2}e^2 - 2e \cos \varepsilon + \frac{1}{2}e^2 \cos 2\varepsilon.\end{aligned}$$

Substituting the values of $\cos \varepsilon$, and $\cos 2\varepsilon$, we have

$$\left(\frac{r}{a}\right)^2 = 1 + \frac{3}{2}e^2 - \frac{4}{1}J_{\lambda}^{(1)} \cos g - \frac{4}{4}J_{2\lambda}^{(2)} \cos 2g - \frac{4}{9}J_{3\lambda}^{(3)} \cos 3g - \text{etc.}$$

To find an expression for the factor $\frac{\sin I}{a} \cdot \frac{r'}{a'} \sin (f + \Pi')$, for brevity, we let

$$c_1 = \frac{\sin I}{a} \cdot \cos \phi' \cos \Pi', \quad c_2 = \frac{\sin I}{a} \cdot \sin \Pi',$$

and from the known expressions for $\frac{r'}{a'} \frac{\sin f'}{\cos \phi'}$, $\frac{r'}{a'} \cos f'$, we get

$$\begin{aligned}\frac{\sin I}{a} \cdot \frac{r'}{a'} \sin (f + \Pi') &= \left[J_{\lambda'}^{(0)} + J_{\lambda'}^{(2)} \right] c_1 \sin g' + \frac{1}{2} \left[J_{2\lambda'}^{(1)} + J_{2\lambda'}^{(3)} \right] c_1 \sin 2g' + \text{etc.} \\ &\quad - \frac{3}{2}e'c_2 + \left[J_{\lambda'}^{(0)} - J_{\lambda'}^{(2)} \right] c_2 \cos g' + \frac{1}{2} \left[J_{2\lambda'}^{(1)} - J_{2\lambda'}^{(3)} \right] c_2 \cos 2g' + \text{etc.}\end{aligned}$$

In the same way, if

$$c_3 = \frac{\sin I}{a} \cdot \cos \phi \cos \Pi, \quad c_4 = \frac{\sin I}{a} \cdot \sin \Pi,$$

we find

$$\left. \begin{aligned}\frac{\sin I}{a} \cdot \frac{r}{a} \sin (f + \Pi) &= \left[J_{\lambda}^{(0)} + J_{\lambda}^{(2)} \right] c_3 \sin g + \frac{1}{2} \left[J_{2\lambda}^{(1)} + J_{2\lambda}^{(3)} \right] c_3 \sin 2g + \text{etc.} \\ &\quad - \frac{3}{2}ec_4 + \left[J_{\lambda}^{(0)} - J_{\lambda}^{(2)} \right] c_4 \cos g + \frac{1}{2} \left[J_{2\lambda}^{(1)} - J_{2\lambda}^{(3)} \right] c_4 \cos 2g + \text{etc.}\end{aligned} \right\} \quad (6)$$

By means of the expressions for the factors

$$\left(\frac{r}{a}\right)^2, \quad \frac{\sin I}{a} \cdot \frac{r'}{a'} \sin (f + \Pi'), \quad \frac{\sin I}{a} \cdot \frac{r}{a} \cdot \sin (f + \Pi),$$

just given, we can form those for

$$\frac{3}{4} \left[\frac{r'^2}{a'^2} - \frac{1}{a^2} \frac{r^2}{a^2} \right]^2$$

$$\frac{3}{2} \frac{\sin I}{a} \cdot \frac{r'}{a'} \sin (f' + \Pi') \left[\frac{r'^2}{a'^2} - \frac{1}{a^2} \frac{r^2}{a^2} \right]$$

$$\frac{3}{2} \frac{\sin^2 I}{a^2} \cdot \frac{r'^2}{a'^2} \sin^2 (f' + \Pi')$$

$$\frac{3}{2} \frac{\sin I}{a} \cdot \frac{r}{a} \sin (f + \Pi) \left[\frac{r'^2}{a'^2} - \frac{1}{a^2} \frac{r^2}{a^2} \right]$$

$$\frac{3}{2} \frac{\sin^2 I}{a^2} \cdot \frac{r}{a} \sin (f + \Pi) \cdot \frac{r'}{a'} \sin (f' + \Pi')$$

CHAPTER IV.

Derivation of the Equations for Determining the Perturbations of the Mean Anomaly, the Radius Vector, and the Latitude, together with Equations for Finding the Values of the Arbitrary Constants of Integration.

HANSEN's expressions for the general perturbations are

$$n_0 z = n_0 t + g_0 + n_0 \int \left[\bar{W}_0 + \frac{d\bar{W}_0}{dt} \cdot \delta z + v^2 \right] dt$$

$$v = C - \frac{1}{2} \int \left[\frac{dW_0}{dt} + \frac{d^2\bar{W}_0}{dt^2} \cdot \delta z \right] dt$$

$$\frac{dR_0}{dt} = h r_{a_0}^{\rho} \sin (\omega - \bar{f}) \left(\frac{d\Omega}{dZ} \right) \cos i,$$

where

$$\begin{aligned} \frac{dW_0}{dt} = h_0 \left\{ 2 \frac{\rho}{r} \cos (\bar{f} - \omega) - 1 + 2 \frac{h^2 \rho}{h_0^2 a_0 \cos^2 \varphi_0} [\cos (\bar{f} - \omega) - 1] \right\} \left(\frac{d\Omega}{dv} \right) \\ + 2h_0 \frac{\rho}{r} \sin (\bar{f} - \omega) r \left(\frac{d\Omega}{dr} \right). \end{aligned}$$

In this chapter we will show how these expressions are derived from the equations of motion, and from quantities already known.

The equations for the undisturbed motion of m around the Sun are

$$\frac{d^2 x}{dt^2} + k^2 (1 + m) \frac{x}{r^3} = 0$$

$$\frac{d^2 y}{dt^2} + k^2 (1 + m) \frac{y}{r^3} = 0$$

$$\frac{d^2 z}{dt^2} + k^2 (1 + m) \frac{z}{r^3} = 0$$

The effect of the disturbing action of a body m' on the motion of m around the Sun is given by the expressions

$$m'k^2\left(\frac{x'-x}{\Delta^3} - \frac{x'}{r'^3}\right), \quad m'k^2\left(\frac{y'-y}{\Delta^3} - \frac{y'}{r'^3}\right), \quad m'k^2\left(\frac{z'-z}{\Delta^3} - \frac{z'}{r'^3}\right).$$

Introducing these into the equations given above we have in the case of disturbed motion

$$\begin{aligned} \frac{d^2x}{dt^2} + k^2(1+m) \frac{x}{r^3} &= m'k^2\left(\frac{x'-x}{\Delta^3} - \frac{x'}{r'^3}\right) \\ \frac{d^2y}{dt^2} + k^2(1+m) \frac{y}{r^3} &= m'k^2\left(\frac{y'-y}{\Delta^3} - \frac{y'}{r'^3}\right) \\ \frac{d^2z}{dt^2} + k^2(1+m) \frac{z}{r^3} &= m'k^2\left(\frac{z'-z}{\Delta^3} - \frac{z'}{r'^3}\right) \end{aligned} \tag{1}$$

The second members of equations (1) show the difference between the action of the body m' on m and on the Sun. The action of any member of bodies m', m'', m''' , etc., can be included in the second members of these equations, since the action of all will be similar to that of m' .

The second members can be put in more convenient form if we make use of the function

$$\Omega = \frac{m'}{1+m} \left(\frac{1}{\Delta} - \frac{xx' + yy' + zz'}{r'^3} \right).$$

Differentiating relative to x

$$\frac{d\Omega}{dx} = \frac{m'}{1+m} \left(-\frac{1}{\Delta^2} \cdot \frac{d\Delta}{dx} - \frac{x'}{r'^3} \right).$$

But since

$$\Delta^2 = (x' - x)^2 + (y' - y)^2 + (z' - z)^2,$$

we have

$$\frac{d\Delta}{dx} = -\frac{x'-x}{\Delta};$$

and hence

$$(1 + m) \frac{d\Omega}{dx} = m' \left(\frac{x' - x}{A^3} - \frac{x'}{r'^3} \right).$$

In the same way we derive the partial differential coefficients with respect to y and z .

The equations (1) then become

$$\begin{aligned} \frac{d^2x}{dt^2} + k^2(1 + m) \frac{x}{r^3} &= k^2(1 + m) \frac{d\Omega}{dx} \\ \frac{d^2y}{dt^2} + k^2(1 + m) \frac{y}{r^3} &= k^2(1 + m) \frac{d\Omega}{dy} \\ \frac{d^2z}{dt^2} + k^2(1 + m) \frac{z}{r^3} &= k^2(1 + m) \frac{d\Omega}{dz} \end{aligned} \quad (2)$$

Let X, Y, Z , be the disturbing forces represented by the second members of equations (2),

R , the disturbing force in the direction of the disturbed radius-vector,

S , the disturbing force, in the plane of the orbit, perpendicular to the disturbed radius-vector, and positive in the direction of the motion.

If f be the angle between the line of apsides and the radius-vector, the angle between this line and the direction of S will be $90^\circ + f$. We then have

$$X = -S \sin f, \quad Y = S \cos f.$$

In case of R , we have

$$R = X \frac{x}{r} + Y \frac{y}{r};$$

and for S ,

$$S = Y \frac{x}{r} - X \frac{y}{r}.$$

From these we find

$$\begin{aligned} X &= R \frac{x}{r} - S \frac{y}{r} \\ Y &= R \frac{y}{r} + S \frac{x}{r}. \end{aligned}$$

If we wish to use polar coördinates we have

$$\frac{d\Omega}{dx} = R \cos f - S \sin f$$

$$\frac{d\Omega}{dy} = R \sin f + S \cos f.$$

From

$$x = r \cos f, \quad y = r \sin f,$$

we find

$$dx = dr \cos f - r df \sin f$$

$$dy = dr \sin f + r df \cos f$$

$$d^2x = d^2r \cos f - r d^2f \sin f - 2dr df \sin f - r df^2 \cos f$$

$$d^2y = d^2r \sin f + r d^2f \cos f + 2dr df \cos f - r df^2 \sin f$$

From the expressions for dx and dy we find

$$dy \cos f - dx \sin f = r df$$

$$dx \cos f + dy \sin f = dr,$$

and hence

$$\frac{d\Omega}{dx} = -\frac{1}{r} \cdot \frac{d\Omega}{df} \sin f + \frac{d\Omega}{dr} \cos f$$

$$\frac{d\Omega}{dy} = \frac{1}{r} \cdot \frac{d\Omega}{df} \cos f + \frac{d\Omega}{dr} \sin f;$$

from which we see that

$$R = k^2 (1 + m) \frac{d\Omega}{dr}, \quad S = k^2 (1 + m) \frac{1}{r} \frac{d\Omega}{df}.$$

If we multiply the expression for d^2x by $\cos f$, that of d^2y by $\sin f$, and add, we obtain

$$d^2x \cos f + d^2y \sin f = d^2r - r df^2.$$

In a similar manner we find

$$d^2y \cos f - d^2x \sin f = r \, d^2f + 2dr \, df.$$

Operating on equations (2) in the same way, we have

$$\begin{aligned} \frac{d^2x}{dt^2} \cos f + \frac{d^2y}{dt^2} \sin f + \frac{k^2(1+m)}{r^2} &= X \cos f + Y \sin f = R \\ \frac{d^2y}{dt^2} \cos f - \frac{d^2x}{dt^2} \sin f &= Y \cos f - X \sin f = S \end{aligned}$$

Comparing the two sets of equations, we have

$$\begin{aligned} r \frac{d^2f}{dt^2} + 2 \frac{dr}{dt} \frac{df}{dt} &= k^2(1+m) \frac{1}{r} \frac{d\Omega}{df} \\ \frac{d^2r}{dt^2} - r \frac{d^2f^2}{dt^2} + \frac{k^2(1+m)}{r^2} &= k^2(1+m) \frac{d\Omega}{dr} \end{aligned} \quad (3)$$

The second members of equations (1) and (2) are small, and in a first approximation to the motion of m relative to the Sun, we can neglect them. The integration of equations (2) introduces six arbitrary constants; and the integration of equations (3) introduces four. These constants are the elements which determine the undisturbed motion of m around the Sun. Having these elements, let

- a_0 the semi-major axis,
- n_0 the mean motion,
- g_0 the mean anomaly for the instant $t = 0$,
- e_0 the eccentricity,
- ϕ_0 the angle of eccentricity,
- π_0 the angle between the axis of x and the perihelion,
- v_0 the angle between the axis of x and the radius-vector,
- f_0 the true anomaly,
- ε_0 the eccentric anomaly.

These elements are constants, and give the position of the body for the epoch, or for $t = 0$. Let us now take a system of variable elements, functions of the time, and let them be designated as before, omitting the subscript zero, and writing χ in place

of π_0 . The former system may be regarded as the particular values which these elements have at the instant $t = 0$.

In Elliptic motion we have

$$\begin{aligned} nt + g_0 &= \varepsilon - e \sin \varepsilon \\ r \cos f &= a \cos \varepsilon - ae \\ r \sin f &= a \cos \phi \sin \varepsilon \\ v &= f + \chi \\ a^3 n^2 &= k^2 (1 + m) \end{aligned}$$

Now let $n_0 z$ be the mean anomaly which by means of the constant elements gives the same value for the true longitude that is given by the system of variable elements. Further, let the quantities depending on $n_0 z$ be designated by a superposed dash, and let the true disturbed value of r be given by the relation $r = r(1 + v)$.

We have then

$$\begin{aligned} n_0 z &= \bar{\varepsilon} - e_0 \sin \bar{\varepsilon} \\ \bar{r} \cos \bar{f} &= a_0 \cos \bar{\varepsilon} - a_0 e_0 \\ \bar{r} \sin \bar{f} &= a_0 \cos \phi_0 \sin \bar{\varepsilon} \\ v &= \bar{f} + \pi_0 \\ a_0^3 n_0^2 &= k^2 (1 + m). \end{aligned}$$

We will now first give BRÜNNOW'S method of finding expressions for the perturbation of the time, and of the radius vector.

Neglecting the mass m , multiplying the first of equations (1) by y , the second by x , we have

$$x \frac{dy}{dt} - y \frac{dx}{dt} = \int (Yx - Xy) dt + C,$$

C being the constant of integration.

Introducing

$$\cos f = \frac{x}{r}, \text{ and } \sin f = \frac{y}{r},$$

into equations (2), neglecting the mass m , we find

$$\begin{aligned}\frac{d^2x}{dt^2} + \frac{k^2 \cos f}{r^3} &= X \\ \frac{d^2y}{dt^2} + \frac{k^2 \sin f}{r^3} &= Y\end{aligned}\tag{4}$$

We have also

$$\begin{aligned}\frac{dx}{dt} &= \cos f \cdot \frac{dr}{dt} - r \sin f \cdot \frac{df}{dt} \\ \frac{dy}{dt} &= \sin f \cdot \frac{dr}{dt} + r \cos f \cdot \frac{df}{dt};\end{aligned}$$

and hence

$$x \frac{dy}{dt} - y \frac{dx}{dt} = r^2 \cdot \frac{df}{dt},$$

or

$$r^2 \cdot \frac{df}{dt} = \int (Yx - Xy) dt + C;$$

and

$$r^2 \cdot \frac{df}{dt} = \int Sr \cdot dt + C.$$

In the undisturbed motion we have

$$r_0^2 \cdot \frac{df_0}{dt} = k \sqrt{p_0},$$

p_0 being the semi-parameter.

Hence

$$\begin{aligned}r^2 \frac{df}{dt} &= \int Sr \cdot dt + k \sqrt{p_0} \\ &= k \sqrt{p}.\end{aligned}$$

From these relations we derive

$$\frac{\sqrt{\bar{p}}}{\sqrt{p_0}} = 1 + \frac{1}{k\sqrt{p_0}} \int Sr \cdot dt, \quad (5)$$

and also

$$\frac{\sqrt{p_0}}{\sqrt{p}} = 1 - \frac{1}{k\sqrt{p_0}} \int \frac{\sqrt{p_0}}{\sqrt{p}} Sr \cdot dt \quad (6)$$

If we eliminate $\frac{1}{r^2}$ from equations (4), noting that

$$r^2 \frac{df}{dt} = k\sqrt{\bar{p}}, \quad \frac{1}{p} \cdot \frac{d\sqrt{p}}{dt} = \frac{1}{k} \cdot \frac{1}{p} \cdot Sr,$$

we have

$$\begin{aligned} \frac{dx}{dt} + \frac{k \sin f}{\sqrt{\bar{p}}} &= \int \left[X - \frac{\sin f}{p} \cdot Sr \right] dt, \\ \frac{dy}{dt} - \frac{k \cos f}{\sqrt{\bar{p}}} &= \int \left[Y - \frac{\cos f}{p} \cdot Sr \right] dt, \end{aligned} \quad (7)$$

neglecting the constants of integration.

Since $r = \bar{r}(1 + \nu)$, we have also

$$x = \bar{x}(1 + \nu), \quad y = \bar{y}(1 + \nu).$$

The equations (7) then become

$$\begin{aligned} \bar{x} \cdot \frac{d\nu}{dt} + (1 + \nu) \frac{d\bar{x}}{dt} + \frac{k \sin f}{\sqrt{\bar{p}}} &= \int \left(X - \frac{\sin f}{p} \cdot Sr \right) dt \\ \bar{y} \cdot \frac{d\nu}{dt} + (1 + \nu) \frac{d\bar{y}}{dt} - \frac{k \cos f}{\sqrt{\bar{p}}} &= \int \left(Y + \frac{\cos f}{p} \cdot Sr \right) dt \end{aligned} \quad (8)$$

From the equations

$$\bar{x} = a_0 \cos \bar{\varepsilon} - a_0 e_0, \quad \bar{y} = a_0 \cos \bar{\phi}_0 \sin \bar{\varepsilon}_0,$$

we have

$$dx = -a_0 \sin \varepsilon d\varepsilon$$

$$dy = a_0 \cos \phi_0 \cdot \cos \varepsilon d\varepsilon.$$

Then since

$$dg = \frac{r}{a_0} d\varepsilon, \quad df = \cos \phi \cdot \frac{a_0^2}{r^3} dg, \quad \frac{df}{dz} = \frac{k^2}{hr^2}, \quad h_0 = \frac{k}{\sqrt{p_0}},$$

using the values of $\sin \varepsilon$, $\cos \varepsilon$, in terms of $\sin f$, $\cos f$, we find

$$\frac{dx}{dz} = -\frac{k \sin \bar{f}}{\sqrt{p_0}}, \quad \frac{dy}{dz} = \frac{\cos \bar{f} + e_0}{\sqrt{p_0}}.$$

And these give

$$\begin{aligned} \frac{k \sin \bar{f}}{\sqrt{p}} &= -\frac{dx}{dz} \cdot \frac{\sqrt{p_0}}{\sqrt{p}}, \\ \frac{k \cos \bar{f}}{\sqrt{p}} &= \frac{dy}{dz} \cdot \frac{\sqrt{p_0}}{\sqrt{p}} - \frac{ke_0}{\sqrt{p}} \\ &= \frac{dy}{dz} \cdot \frac{\sqrt{p_0}}{\sqrt{p}} - \frac{ke_0}{\sqrt{p_0}} - \int \frac{e_0}{p} \cdot Sr dt \end{aligned}$$

The equations (8) then become

$$\begin{aligned} x \frac{dv}{dt} + \frac{dx}{dz} \left[(1+v) \frac{dz}{dt} - \frac{\sqrt{p_0}}{\sqrt{p}} \right] &= \int (X - \frac{\sin \bar{f}}{p} \cdot Sr) dt \\ y \frac{dv}{dt} + \frac{dy}{dz} \left[(1+v) \frac{dz}{dt} - \frac{\sqrt{p_0}}{\sqrt{p}} \right] &= \int (Y + \frac{\cos \bar{f} + e_0}{p} \cdot Sr) dt, \end{aligned} \tag{9}$$

the constant $-\frac{ke_0}{\sqrt{p}}$ being included in the integral.

We will now transform equations (9), and for this purpose we multiply the first by $\frac{dy}{dz}$, the second by $\frac{dx}{dz}$, and noting that

$$x \frac{dy}{dz} - y \frac{dx}{dz} = k\sqrt{p},$$

we have

$$\frac{d\nu}{dt} = \frac{\cos \bar{f} + e_0}{p_0} \int \left(X - \frac{\sin \bar{f}}{p} \cdot Sr \right) dt + \frac{\sin \bar{f}}{p_0} \int \left(Y + \frac{(\cos \bar{f} + e_0)}{p} \right) Sr dt \quad (10)$$

Now multiply the first of (9) by y , the second by x , putting for $\sqrt[3]{p_0}$ its value given by (6), noting that

$$\bar{y} \frac{d\bar{x}}{dt} - \bar{x} \frac{d\bar{y}}{dt} = -k\sqrt[3]{p_0},$$

we have

$$\begin{aligned} (1 + \nu) \frac{dz}{dt} = 1 - \frac{1}{k\sqrt[3]{p_0}} \int \frac{p_0}{p} \cdot Sr dt - \frac{y}{k\sqrt[3]{p_0}} \int \left(X - \frac{\sin \bar{f}}{p} \cdot Sr \right) dt \\ + \frac{\bar{x}}{k\sqrt[3]{p_0}} \int \left(Y + \frac{\cos \bar{f} + e_0}{p} \cdot Sr \right) dt \end{aligned} \quad (11)$$

We can write $\frac{dz}{dt}$ in the form

$$\frac{dz}{dt} = 2(1 + \nu) \frac{dz}{dt} - (1 + \nu)^2 \cdot \frac{dz}{dt} + \nu^2 \cdot \frac{dz}{dt}.$$

We have

$$(1 + \nu) = \frac{r}{r}, \quad \frac{df}{dt} = \frac{df}{dz} \cdot \frac{dz}{dt}, \quad \frac{df}{dt} = n \frac{a^2}{r^2} \cos \phi,$$

$$\frac{df}{dt} = n_0 \cdot \frac{a_0^2}{r^2} \cdot \cos \phi_0, \quad a^3 n^2 = a_0^3 n_0^2.$$

Making use of these relations we find

$$\frac{dz}{dt} = \frac{1}{(1 + \nu)^2} \cdot \frac{1}{\sqrt[3]{p_0}};$$

and for $\frac{dz}{dt}$ given above we have

$$\frac{dz}{dt} = 2(1 + \nu) \cdot \frac{dz}{dt} - \frac{1}{\sqrt[3]{p_0}} + \frac{\nu^2}{(1 + \nu)^2} \cdot \frac{1}{\sqrt[3]{p_0}}.$$

The equation (11) is thus changed into

$$\begin{aligned} \frac{dz}{dt} = 1 - \frac{1}{k\sqrt{p_0}} \int \left(1 + 2\frac{\sqrt{p_0}}{\sqrt{p}}\right) Sr dt - \frac{2y}{k\sqrt{p_0}} \int \left(X - \frac{\sin f}{p} Sr\right) dt \\ + \frac{2x}{k\sqrt{p_0}} \int \left(Y + \frac{\cos f + e_0}{p} Sr\right) dt + \frac{\nu^2}{(1+\nu)^2} \cdot \frac{\sqrt{p}}{\sqrt{p_0}}. \end{aligned} \quad (12)$$

The equations (10) and (12) can be put in briefer form.

Let

$$X_s = X - \frac{\sin f}{p} Sr, \quad Y_c = Y + \frac{\cos f + e_0}{p} Sr.$$

Then

$$\frac{d\nu}{dt} = \frac{\cos f + e_0}{p_0} \int X_s dt + \frac{\sin f}{p_0} \int Y_c dt, \quad (13)$$

$$\frac{dz}{dt} = 1 - \frac{1}{k\sqrt{p_0}} \int \left(1 + 2\frac{\sqrt{p_0}}{\sqrt{p}}\right) Sr dt - \frac{2y}{k\sqrt{p_0}} \int X_s dt + \frac{2x}{k\sqrt{p_0}} \int Y_c dt$$

The values of x , y , found in these equations we get from

$$\begin{aligned} x &= x_0 + \frac{dx_0}{dt} (z - t) + \frac{1}{2} \cdot \frac{d^2 x_0}{dt^2} (z - t)^2 + \text{etc.} \\ y &= y_0 + \frac{dy_0}{dt} (z - t) + \frac{1}{2} \cdot \frac{d^2 y_0}{dt^2} (z - t)^2 + \text{etc.} \end{aligned} \quad (14)$$

From the expressions for $\frac{dx}{dz}$, $\frac{dy}{dz}$, we have also

$$\begin{aligned} \frac{\cos f + e_0}{p_0} &= \frac{1}{k\sqrt{p_0}} \left(\frac{dy_0}{dt} + \frac{1}{2} \frac{d^2 y_0}{dt^2} (z - t) \right) + \text{etc.} \\ - \frac{\sin f}{p_0} &= \frac{1}{k\sqrt{p_0}} \left(\frac{dx_0}{dt} + \frac{1}{2} \frac{d^2 x_0}{dt^2} (z - t) \right) + \text{etc.} \end{aligned} \quad (15)$$

The quantities given by equations (14) and (15) are found in equations (13) without the integral sign. They can be put under the sign of integration and regarded

as constant if we designate all magnitudes in these factors dependent on t by a Greek letter.

We thus obtain

$$\begin{aligned} \frac{d(z-t)}{dt} = & -\frac{1}{k\sqrt{p_0}} \int \left(1 + 2\frac{\sqrt{p_0}}{\sqrt{p}}\right) Sr dt - \frac{2}{k\sqrt{p_0}} \int (X_s \cdot v - Y_c \cdot \xi) dt \\ & - \frac{2(z-t)}{k\sqrt{p_0}} \int \left(X_s \cdot \frac{dv}{d\tau} - Y_c \cdot \frac{d\xi}{d\tau}\right) dt + v^2 \frac{p}{p_0} \end{aligned} \quad (16)$$

$$\frac{dv}{dt} = \frac{1}{k\sqrt{p_0}} \int \left(X_s \cdot \frac{dv}{d\tau} - Y_c \cdot \frac{d\xi}{d\tau}\right) dt + \frac{(z-t)}{k\sqrt{p_0}} \int \left(X_s \cdot \frac{d^2v}{d\tau^2} - Y_c \cdot \frac{d^2\xi}{d\tau^2}\right) dt$$

These equations include terms of the second order with respect to the mass. If we put

$$W = -\frac{1}{k\sqrt{p_0}} \int \left(1 + \frac{\sqrt{p_0}}{\sqrt{p}}\right) \cdot Sr dt - \frac{2}{k\sqrt{p_0}} \int (X_s \cdot v - Y_c \cdot \xi) dt,$$

we get

$$\left. \begin{aligned} n_0 z &= n_0 t + g_0 + n_0 \int \left[W + \frac{dW}{d\tau} \cdot \delta z + v^2 \right] dt \\ v &= N - \frac{1}{2} \int \left[\frac{dW}{d\tau} + \frac{d^2W}{d\tau^2} \cdot \delta z \right] dt \end{aligned} \right\} \quad (17)$$

In equations (17) g_0 is the mean anomaly for $t=0$; N is the constant of integration in the value of v .

From the value of W given above, we have

$$\frac{dW}{dt} = -\frac{1}{k\sqrt{p_0}} \left(1 + 2\frac{\sqrt{p_0}}{\sqrt{p}}\right) Sr - \frac{2}{k\sqrt{p_0}} (X_s \cdot v - Y_c \cdot \xi).$$

Now since

$$X = \cos \bar{f} \cdot \frac{d\Omega}{dr} - \sin \bar{f} \cdot \frac{1}{r} \cdot \frac{d\Omega}{df}$$

$$Y = \sin \bar{f} \cdot \frac{d\Omega}{dr} + \cos \bar{f} \cdot \frac{1}{r} \cdot \frac{d\Omega}{df}$$

$$R = \frac{d\Omega}{dr}$$

$$S = \frac{1}{r} \cdot \frac{d\Omega}{df}$$

neglecting the common factor $k^2 (1 + m)$,
we have

$$\begin{aligned} \frac{dW}{dt} = & -\frac{1}{k\sqrt{p_0}} \left(1 + 2\frac{\sqrt{p_0}}{\sqrt{p}}\right) \frac{d\Omega}{df} - \frac{2}{k\sqrt{p_0}} \left(\frac{d\Omega}{dr} \cdot \cos \bar{f} - \frac{1}{r} \cdot \sin \bar{f} \cdot \frac{d\Omega}{df}\right) v \\ & + \frac{2}{k\sqrt{p_0}} \left(\frac{d\Omega}{dr} \sin \bar{f} + \frac{1}{r} \frac{d\Omega}{df} \cos \bar{f}\right) \xi + \frac{2}{k\sqrt{p_0}} \left[\frac{\sin \bar{f}}{p} \cdot \frac{d\Omega}{df} \cdot v + \frac{(\cos \bar{f} + e_0)}{p} \cdot \frac{d\Omega}{df} \cdot \xi\right]. \end{aligned}$$

And as

$$v = \rho \sin \omega, \quad \xi = \rho \cos \omega,$$

this becomes

$$\begin{aligned} \frac{dW}{dt} = & \frac{1}{k\sqrt{p_0}} \left[\left(-1 - 2\frac{\sqrt{p_0}}{\sqrt{p}}\right) \frac{d\Omega}{df} - 2\rho \sin \omega \cdot \cos \bar{f} \cdot \frac{d\Omega}{df} + \frac{2}{r} \cdot \rho \sin \omega \sin \bar{f} \cdot \frac{d\Omega}{df} \right. \\ & \left. + 2\rho \cos \omega \cdot \sin \bar{f} \cdot \frac{d\Omega}{dr} + 2\rho \cdot \frac{1}{r} \frac{d\Omega}{df} \cos \omega \cos \bar{f} + 2\rho \cdot \frac{\sin \omega \cdot \sin \bar{f}}{p} \frac{d\Omega}{df} \right. \\ & \left. + 2\rho \frac{\cos \omega \cdot \cos \bar{f}}{p} \frac{d\Omega}{df} + \frac{e_0}{p} \cdot \rho \cos \omega \frac{d\Omega}{df} \right] \\ = & \frac{1}{k\sqrt{p_0}} \left[\left(-1 - 2\frac{\sqrt{p_0}}{\sqrt{p}}\right) \frac{d\Omega}{df} + 2\rho \sin (\bar{f} - \omega) \frac{d\Omega}{dr} + 2\frac{\rho}{r} \cos (\bar{f} - \omega) \frac{d\Omega}{df} \right. \\ & \left. + 2\frac{\rho}{p} \cos (\bar{f} - \omega) \frac{d\Omega}{df} + 2e_0 \cdot \frac{\rho}{p} \cos \omega \frac{d\Omega}{df} \right] \end{aligned}$$

But

$$2e_0 \rho \cos \omega \cdot \frac{h^2}{k^2} - 2p_0 \cdot \frac{h^2}{k^2} = 2\frac{h^2}{k^2} (e_0 \rho \cos \omega - p_0) = -\rho \cdot 2\frac{h^2}{k^2};$$

also

$$h_0 = \frac{k}{\sqrt{p_0}}, \quad h = \frac{k}{\sqrt{p}}.$$

Hence since $k^2(1+m)$ is included in X, Y, R, S , we have

$$\begin{aligned} \frac{dW}{dt} = h_0 \left[2 \frac{\rho}{r} \cos(\bar{f} - \omega) - 1 + \frac{2\rho \cdot h^2}{k^2} (\cos(\bar{f} - \omega) - 1) \right] \frac{d\Omega}{df} \\ + 2h_0\rho \cdot \sin(\bar{f} - \omega) \frac{d\Omega}{dr} \end{aligned} \quad (18)$$

If we write $h_0^2 \cdot a_0 \cos^2 \phi_0$ in place of k^2 in equation (18), we have the same expression for $\frac{dW}{dt}$ as that given by HANSEN.

Equations (17) and (18) are fundamental in HANSEN'S method of computing the perturbations. We will now give HANSEN'S method of deriving them.

Using the same notation as before, we have, since

$$\frac{a}{r} = \frac{1+e \cos f}{\cos^2 \varphi},$$

also

$$\frac{r}{a_0} = \frac{\cos^2 \varphi_0}{1+e_0 \cos f};$$

hence

$$\frac{r \cdot a}{r \cdot a_0} = \frac{1+e \cos f}{\cos^2 \varphi} \cdot \frac{\cos^2 \varphi_0}{1+e_0 \cos f}.$$

Using $f + \pi_0 - \chi$ in place of f , and developing, we get

$$\frac{\bar{r} \cdot a}{r \cdot a_0} = \frac{\bar{r} + \bar{r} \cos \bar{f} \cdot e \cos(\chi - \pi_0) + \bar{r} \sin \bar{f} \cdot e \sin(\chi - \pi_0)}{a_0 \cos^2 \varphi_0}.$$

Let us put

$$\begin{aligned} e \sin(\chi - \pi_0) &= \eta \cos^2 \phi_0, \\ e \cos(\chi - \pi_0) &= \xi \cos^2 \phi_0 + e_0; \end{aligned} \quad (19)$$

since $e = \sin \phi$, we have

$$\cos^2 \phi = \cos^2 \phi_0 (1 - 2e_0 \xi - \cos^2 \phi_0 \xi^2 - \cos^2 \phi_0 \eta^2).$$

With this value of $\cos^2 \phi$, and $r = a_0 \cos^2 \phi_0 - e_0 r \cos f$,

we find

$$\begin{aligned} \frac{r \cdot a}{r \cdot a_0} &= \frac{a_0 \cos^2 \phi_0 - e_0 \cdot \bar{r} \cos \bar{f} + \bar{r} \cos \bar{f} (\xi \cos^2 \phi_0 + e_0) + \bar{r} \sin \bar{f} \cdot \eta \cos^2 \phi_0}{a_0 \cos^2 \phi_0} \\ &= \frac{a_0 \cos^2 \phi_0 + \bar{r} \cos \bar{f} \cdot \xi \cos^2 \phi_0 + \bar{r} \sin \bar{f} \cdot \eta \cos^2 \phi_0}{a_0 \cos^2 \phi_0 (1 - 2e_0 \xi - \cos^2 \phi_0 \xi^2 - \cos^2 \phi_0 \eta^2)}; \end{aligned}$$

and hence

$$\frac{r \cdot a}{r \cdot a_0} = \frac{1 + \xi \cdot \frac{r}{a_0} \cos \bar{f} + \eta \cdot \frac{r}{a_0} \sin \bar{f}}{1 - 2e_0 \xi - \cos^2 \phi_0 \xi^2 - \cos^2 \phi_0 \eta^2}.$$

From

$$\frac{dv}{dt} = \frac{df}{dt} = \frac{d\bar{f}}{dz} \cdot \frac{dz}{dt},$$

and

$$\frac{df}{dt} = \frac{k\sqrt{p(1+m)}}{r^2},$$

we have

$$\frac{d\bar{f}}{dz} = n \cdot \frac{a^2}{r^2} \cdot \cos \phi.$$

In like manner we find

$$\frac{d\bar{f}}{dz} = n_0 \cdot \frac{a_0^2}{r^2} \cdot \cos \phi_0.$$

We have therefore

$$\frac{dz}{dt} = \frac{n \cdot a^2 \cdot r^2 \cdot \cos \phi}{n_0 \cdot a_0^2 \cdot r^2 \cdot \cos \phi_0}$$

If we put $\frac{n}{n_0} = 1 + b$, substitute the values of $\frac{r.a}{r.a_0}$, and $\cos^2 \phi$, we get

$$\frac{dz}{dt} = (1 + b) \frac{(1 + \xi \cdot \frac{r}{a_0} \cos \bar{f} + \eta \cdot \frac{r}{a_0} \sin \bar{f})^2}{(1 - 2e_0 \xi - \cos^2 \phi_0 \xi^2 - \cos^2 \phi_0 \eta^2)^{\frac{3}{2}}} \quad (20)$$

Further, in the case of ν , we have

$$1 + \nu = \frac{r}{r'}$$

Then since

$$a^3 n^2 = a_0^3 n_0^2, \quad \frac{n}{n_0} = (1 + b),$$

and

$$\frac{\cos^2 \phi}{\cos^2 \phi_0} = (1 - 2e_0 \xi - \cos^2 \phi_0 \xi^2 - \cos^2 \phi_0 \eta^2),$$

we have

$$(1 + \nu) = \frac{1 - 2e_0 \xi - \cos^2 \phi_0 \xi^2 - \cos^2 \phi_0 \eta^2}{(1 + \frac{r}{a_0} \cos \bar{f} \cdot \xi + \frac{r}{a_0} \sin \bar{f} \cdot \eta)^{\frac{3}{2}} (1 + b)^{\frac{3}{2}}}.$$

If we let

$$A = 1 + \frac{r}{a_0} \cos \bar{f} \cdot \xi + \frac{r}{a_0} \sin \bar{f} \cdot \eta,$$

$$B = 1 - 2e_0 \xi - \cos^2 \phi_0 \xi^2 - \cos^2 \phi_0 \eta^2,$$

$$\frac{h}{h_0} = \frac{(1 + b)^{\frac{1}{2}}}{B^{\frac{1}{2}}},$$

we find

$$\frac{dz}{dt} = (1 + b) \frac{A^2}{B^{\frac{3}{2}}}, \quad (1 + \nu) = \frac{B}{A(1 + b)^{\frac{3}{2}}}.$$

From the latter we have

$$\left(\frac{\nu}{1+\nu}\right)^2 = 1 - 2(1+b)^{\frac{2}{3}} \frac{A}{B} + (1+b)^{\frac{4}{3}} \cdot \frac{A^2}{B^2}.$$

Hence

$$\begin{aligned} \left(\frac{\nu}{1+\nu}\right)^2 \frac{h_0}{h} &= \frac{h_0}{h} - 2(1+b)^{\frac{1}{3}} \frac{A}{B^{\frac{3}{2}}} + (1+b) \frac{A^2}{B^{\frac{3}{2}}}, \\ &= \frac{h_0}{h} - \frac{2h}{h_0} A + \frac{dz}{dt}. \end{aligned}$$

If we put

$$W = 2 \frac{h}{h_0} - \frac{h_0}{h} - 1 + 2 \frac{h}{h_0} \cdot \xi \cdot \frac{r}{a_0} \cos f + 2 \frac{h}{h_0} \cdot \eta \cdot \frac{r}{a_0} \sin f,$$

we have

$$\frac{dz}{dt} = 1 + W + \frac{h_0}{h} \left(\frac{\nu}{1+\nu}\right)^2. \quad (21)$$

We have yet to express $\frac{h_0}{h}$ in terms of the elements.

From

$$B = 1 - 2e_0 \xi - \xi^2 \cdot \cos^2 \phi_0 - \eta^2 \cdot \cos^2 \phi_0 = \frac{\cos^2 \varphi}{\cos^2 \varphi_0},$$

and from

$$\frac{n^2}{n_0^2} = \frac{a_0^3}{a^3},$$

$$1 + b = \frac{n}{n_0},$$

we have

$$\frac{h}{h_0} = \left(\frac{n}{n_0}\right)^{\frac{1}{3}} \cdot \frac{\cos \varphi_0}{\cos \varphi},$$

or

$$\frac{h}{h_0} = \frac{an}{\cos \varphi} \cdot \frac{\cos \varphi_0}{a_0 n_0}.$$

If we put

$$h_c = \frac{a_0 n_0}{\cos \varphi_0},$$

we have

$$h = \frac{an}{\cos \varphi}.$$

These values of h and h_0 being substituted in the expressions for W , $\frac{dz}{dt}$ is found expressed in terms of the elements and of ν , in a very simple form. To find the relation between $\frac{dz}{dt}$ and ν , we use the equation

$$(1 + \nu)^2 = \frac{B^2}{A^2(1+b)^3};$$

and as this is also equal to $\frac{h_0}{h} \frac{dz}{dt}$,

we find

$$\frac{dz}{dt} = \frac{h_0}{h} \cdot \frac{1}{(1+\nu)^2}. \quad (22)$$

For the purpose of keeping the formulæ simple and compact, HANSEN makes use of the device of designating the time, and the functions of the time other than the elements, by different letters.

Thus for $t, r, \varepsilon, f, z, \nu, x, y$, we write,

$\tau, \rho, \eta, \omega, \zeta, \beta, \xi, v$, respectively.

Whenever we integrate, these new symbols are to be treated as constants, noting that the original symbols are used after integration.

If in equation (21) we introduce τ instead of t we shall have

$$\frac{d\xi}{d\tau} = 1 + W + \frac{h_0}{h} \left(\frac{\beta}{1+\beta} \right)^2, \quad (23)$$

where

$$W = 2 \frac{h}{h_0} - \frac{h_0}{h} - 1 + 2 \frac{h}{h_0} \cdot \xi \cdot \frac{\bar{\rho}}{a_0} \cos \bar{\omega} + 2 \frac{h}{h_0} \cdot \eta \cdot \frac{\bar{\rho}}{a_0} \sin \bar{\omega}.$$

We have also

$$\frac{d\xi}{d\tau} = \frac{h_0}{h(1+\beta)^2}. \quad (24)$$

The coördinates of a body vary not only with the time but also with the variable elements. In computations where the elements are assumed constant, that part of the velocity of change in the coördinates arising from variable elements must, evidently, be put equal to zero. Coördinates which have the property of retaining for themselves and for their first differential coefficients the same form in disturbed as in undisturbed motion, HANSEN calls ideal coördinates.

If L be a function of ideal coördinates, it can be expressed as a function of the time and of the constant elements. Thus let the time, as it enters into quantities other than the elements, be itself variable and, as before, designated by τ .

The function dependent on t , τ , and the elements we designate by Λ . Then

$$\frac{dL}{dt} = \frac{\overline{d\Lambda}}{d\tau},$$

or

$$dL = \left(\frac{\overline{d\Lambda}}{d\tau} \right) dt$$

where the superposed dash shows that after differentiation τ is to be changed into t .

Let us write the equation (24) in the form

$$\frac{d\xi}{d\tau} (1 + \beta)^2 = \frac{h_0}{h}.$$

Differentiating relative to τ , we have

$$\frac{d\beta}{d\tau} = -\frac{\frac{d^2\zeta}{d\tau^2}}{2\frac{d\zeta}{d\tau}}(1+\beta).$$

The differentiation of (23) also relative to τ gives

$$\frac{d^2\zeta}{d\tau^2} = \frac{dW}{d\zeta} \cdot \frac{d\zeta}{d\tau} + \frac{h_0}{h} \cdot \frac{2\beta}{(1+\beta)^3} \cdot \frac{d\beta}{d\tau}.$$

Eliminating $\frac{h_0}{h}$ by means of (24), we have

$$\frac{\frac{d^2\zeta}{d\tau^2}}{\frac{d\zeta}{d\tau}} = \frac{dW}{d\zeta} + \frac{2\beta}{1+\beta} \cdot \frac{d\beta}{d\tau}.$$

Substituting in the expression for $\frac{d\beta}{d\tau}$ we have

$$\frac{d\beta}{d\tau} = -\frac{1}{2} \cdot \frac{dW}{d\zeta}.$$

Since ν is an ideal coördinate, we get from this

$$\nu = N - \frac{1}{2} \int \left(\frac{dW}{d\zeta} \right) dt, \quad (25)$$

N being the constant of integration, and the dash having the same signification as before.

This expression for ν is a transformation of that given in the equation

$$1 + \nu = \frac{1 - 2e_0\xi - \cos^2\varphi_0 \cdot \xi^2 - \cos^2\varphi_0 \cdot \eta^2}{(1+b)^{\frac{1}{2}}(1+\xi \cdot \frac{r}{a_0} \cos \bar{f} + \eta \cdot \frac{r}{a_0} \sin \bar{f})}.$$

Since z is also an ideal coördinate, we have from (23)

$$n_0 z = n_0 t + g_0 + n_0 \int \left\{ \overline{W} + \frac{h_0}{h} \left(\frac{\nu}{1+\nu} \right)^2 \right\} dt \quad (26)$$

g_0 being the constant of integration and being the mean anomaly for $t = 0$.

When we consider only terms of the first order with respect to the disturbing force, ζ changes into τ , and we have

$$\left. \begin{aligned} n_0 z &= n_0 t + c_0 + n_0 \int \bar{W}_0 dt \\ \nu &= N - \frac{1}{2} \int \left(\frac{d\bar{W}_0}{d\tau} \right) dt \end{aligned} \right\} \quad (27)$$

where

$$W_0 = 2 \frac{h}{h_0} - \frac{h_0}{h} - 1 + 2 \frac{h}{h_0} \cdot \xi \cdot \frac{\rho}{a_0} \cos \omega + 2 \frac{h}{h_0} \cdot \eta \cdot \frac{\rho}{a_0} \sin \omega, \quad (28)$$

and ρ and ω are functions of τ , being found from

$$\begin{aligned} n_0 \tau + c_0 &= \eta - e_0 \sin \eta \\ \rho \cos \omega &= a_0 \cos \eta - a_0 e_0 \\ \rho \sin \omega &= a_0 \cos \phi_0 \sin \eta. \end{aligned}$$

Also in the last two terms of W_0 , $\frac{h}{h_0}$ is put equal to unity.

When terms of the order of the square and higher powers of the disturbing force are considered, ζ cannot be changed into τ . In this case let

$$n_0 t = n_0 \tau + g_0 + n \delta z.$$

Likewise let

$$n_0 \zeta = n_0 \tau + g_0 + n \delta \zeta$$

where

$$n \delta \zeta \text{ is a function of } \tau \text{ and } t.$$

According to Taylor's theorem we have

$$W = W_0 + \frac{dW_0}{d\tau} \cdot \delta \zeta + \frac{1}{2} \frac{d^2 W_0}{d\tau^2} \cdot \delta \zeta^2 + \text{etc.}$$

the value of W_0 being given by (28).

We then have

$$\frac{dW}{d\zeta} = \frac{dW_0}{d\tau} + \frac{d^2W_0}{d\tau^2} \cdot \delta\zeta + \frac{1}{2} \cdot \frac{d^3W_0}{d\tau^3} \cdot \delta\zeta^2 + \text{etc.}$$

Retaining only terms of the second order, the equations (25) and (26), replacing $\delta\zeta$ by δz , give

$$\begin{aligned} n_0 z &= n_0 t + g_0 + n_0 \int \left[\overline{W}_0 + \frac{d\overline{W}}{d\tau} \cdot \delta z + \nu^2 \right] dt \\ \nu &= N - \frac{1}{2} \int \left[\frac{d\overline{W}_0}{d\tau} + \frac{d^2\overline{W}_0}{d\tau^2} \cdot \delta z \right] dt \end{aligned} \quad (29)$$

The equation (26) has been put in simpler form by HILL. For this purpose from (21) and (22) we have

$$\frac{h_0}{h} \left(\frac{\nu}{1+\nu} \right)^2 = \nu^2 \frac{dz}{dt} = \frac{dz}{dt} - (1 + \overline{W}).$$

Hence

$$\nu^2 \cdot \frac{dz}{dt} = \nu^2 \left(\frac{1+\overline{W}}{1-\nu^2} \right).$$

Developing the second member and adding \overline{W} , we have

$$n_0 z = n_0 t + g_0 + n_0 \int \frac{\overline{W} + \nu^2}{1 - \nu^2} dt. \quad (30)$$

The next step is to express $\frac{dW_0}{dt}$ and $\frac{dh}{dt}$ in terms of the disturbing force. From (19) we find

$$\xi = \frac{e}{\cos^2 \varphi_0} \cdot \cos(\chi - \pi_0) - \frac{e_0}{\cos^2 \varphi_0}$$

$$\eta = \frac{e}{\cos^2 \varphi_0} \cdot \sin(\chi - \pi_0).$$

Using these values of ξ and η , and $e_0 \rho \cos \omega = a_0 \cos^2 \phi_0 - \rho$, in equation (28), we find

$$W_0 = \frac{2\rho}{h_0 a_0 \cos^2 \phi_0} \cdot h e \cos (\chi - \pi_0 - \omega) + \frac{2\rho}{h_0 a_0 \cos^2 \phi_0} \cdot h - \frac{h_0}{h} - 1.$$

Since

$$h = \frac{an}{\cos \varphi} = \frac{k\sqrt{1+m}}{\sqrt{p}},$$

we have from the expression of h already given,

$$h = \frac{k^2(1+m)}{r^2 \cdot \frac{dv}{dt}}.$$

By means of

$$f = \bar{f} - \omega - (\chi - \pi_0 - \omega),$$

$$\frac{p}{r} - 1 = e \cos f,$$

$$h = \frac{an}{\cos \varphi},$$

we may transform the expressions

$$\frac{dv}{dt} = \frac{a^2}{r^2} \cdot n \cos \phi,$$

$$\frac{dr}{dt} = \frac{an}{\cos \varphi} \cdot e \sin f,$$

into

$$r \cdot \frac{dv}{dt} - h = \cos (\bar{f} - \omega) \cdot h e \cos (\chi - \pi_0 - \omega) + \sin (\bar{f} - \omega) \cdot h e \sin (\chi - \pi_0 - \omega)$$

$$\frac{dr}{dt} = \sin (\bar{f} - \omega) \cdot h e \cos (\chi - \pi_0 - \omega) - \cos (\bar{f} - \omega) \cdot h e \sin (\chi - \pi_0 - \omega)$$

Multiplying the first of these equations by $\cos (f - \omega)$, the second by $\sin (f - \omega)$, and adding the results, we have

$$he \cos (\chi - \pi_0 - \omega) = \left(r \frac{dv}{dt} - h \right) \cos (\bar{f} - \omega) + \frac{dr}{dt} \sin (\bar{f} - \omega).$$

Substituting this value of $h.e.\cos (\chi - \pi_0 - \omega)$ in the expression for W_0 , noting that

$$\frac{1}{h_0 a_0 \cos^2 \varphi_0} = \frac{h_0}{k^2(1+m)},$$

we have

$$\begin{aligned} W_0 = & \frac{2h_0\rho}{k^2(1+m)} \cdot \cos (\bar{f} - \omega) r \frac{dv}{dt} + \frac{2h_0\rho}{k^2(1+m)} \cdot \sin (\bar{f} - \omega) \frac{dr}{dt} \\ & - \frac{2\rho}{h_0 a_0 \cos^2 \varphi_0} [\cos (\bar{f} - \omega) - 1] h - \frac{h_0}{h} - 1. \end{aligned}$$

Differentiating relative to the time t alone, τ remaining constant, and having care that all the terms of the expressions be homogeneous, we have

$$\begin{aligned} \frac{dW_0}{dt} = & \frac{2h_0\rho}{k^2(1+m)} \cdot \cos (\bar{f} - \omega) r \frac{d^2v}{dt^2} + \frac{2h_0\rho}{k^2(1+m)} \cdot \sin (\bar{f} - \omega) \cdot \frac{d^2r}{dt^2} \\ & - \frac{2\rho}{h_0 a_0 \cos^2 \varphi_0} [\cos (\bar{f} - \omega) - 1] \frac{dh}{dt} + \frac{h_0}{h} \cdot \frac{dh}{dt}, \end{aligned}$$

and

$$\frac{dh}{dt} = - \frac{k^2(1+m)}{r^2 \left(\frac{dv}{dt} \right)^2} \cdot \frac{d^2v}{dt^2} = - \frac{h^2 r^2}{k^2(1+m)} \cdot \frac{d^2v}{dt^2}.$$

Substituting

$$k^2(1+m) \frac{1}{r^2} \left(\frac{d\Omega}{dv} \right) \text{ for } \frac{d^2v}{dt^2},$$

$$k^2(1+m) \left(\frac{d\Omega}{dr} \right) \text{ for } \frac{d^2r}{dt^2},$$

we have

$$\begin{aligned} \frac{dW_0}{dt} = h_0 \left\{ 2\frac{\rho}{r} \cos(\bar{f} - \omega) - 1 + \frac{2h^2\rho}{h_0 a_0 \cos^2 \varphi_0} [\cos(\bar{f} - \omega) - 1] \right\} \left(\frac{d\Omega}{dv} \right) \\ + 2h_0 \frac{\rho}{r} \sin(\bar{f} - \omega) r \left(\frac{d\Omega}{dr} \right) \end{aligned} \quad (30)$$

$$\frac{dh}{dt} = -h^2 \left(\frac{d\Omega}{dv} \right)$$

This expression for $\frac{dW_0}{dt}$ is the one used by HANSEN in his *Auseinandersetzung*. It is given in a much simpler form in his posthumous memoir, and as the latter is the form in which we will employ it, we will now give the process employed by HANSEN to effect the transformation.

Substituting first the value of h , omitting the dash placed over certain quantities, noting that in the posthumous memoir ϕ takes the place of ω , and remembering that we are here concerned only with terms of the first order with respect to the mass, we have

$$\begin{aligned} \frac{dW}{dt} = \frac{an}{\sqrt{1-e^2}} \left\{ 2\frac{\rho}{r} \cos(f - \omega) - 1 + \frac{2\rho}{a(1-e^2)} [\cos(f - \omega) - 1] \right\} \left(\frac{d\Omega}{df} \right) \\ + 2\frac{an}{\sqrt{1-e^2}} \cdot \frac{\rho}{r} \sin(f - \omega) r \left(\frac{d\Omega}{dr} \right) \end{aligned}$$

From the relation

$$\rho = a(1 - e^2) - e\rho \cos \omega$$

we have

$$\frac{\rho}{a(1-e^2)} = 1 - \frac{e\rho \cos \omega}{a(1-e^2)}.$$

An inspection of the value of $\frac{dW}{dt}$ shows that its expression consists of three parts, one independent of τ , the other two multiplied by $\rho \cos \omega$, and $\rho \sin \omega$, respectively.

Put

$$\frac{dW}{dt} = \frac{d\Xi}{dt} + \frac{dY}{dt} \left(\frac{\rho}{a} \cos \omega + \frac{3}{2} e \right) + \frac{d\Psi}{dt} \cdot \frac{\rho}{a} \sin \omega,$$

and we have

$$\begin{aligned} \frac{d\Xi}{n dt} &= -3 \frac{a}{\sqrt{1-e^2}} \left\{ \left[\frac{ae \cos f}{r} + \frac{e \cos f}{1-e^2} + \frac{1}{1-e^2} \right] \left(\frac{d\Omega}{df} \right) + \frac{ae \sin f}{r} \cdot r \left(\frac{d\Omega}{dr} \right) \right\}, \\ \frac{dY}{n dt} &= 2 \frac{a}{\sqrt{1-e^2}} \left\{ \left[\frac{a \cos f}{r} + \frac{(\cos f + e)}{1-e^2} \right] \left(\frac{d\Omega}{df} \right) + \frac{a \sin f}{r} \cdot r \left(\frac{d\Omega}{dr} \right) \right\}, \\ \frac{d\Psi}{n dt} &= 2 \frac{a}{\sqrt{1-e^2}} \left\{ \left[\frac{a \sin f}{r} + \frac{\sin f}{1-e^2} \right] \left(\frac{d\Omega}{df} \right) - \frac{a \cos f}{r} \cdot r \left(\frac{d\Omega}{dr} \right) \right\}. \end{aligned}$$

But

$$\frac{df}{dg} = \frac{a^2}{r^2} \sqrt{1-e^2} = \frac{ae \cos f}{r \sqrt{1-e^2}} + \frac{e \cos f}{(1-e^2)^{\frac{3}{2}}} + \frac{1}{(1-e^2)^{\frac{3}{2}}},$$

$$\frac{dr}{dg} = \frac{ae \sin f}{\sqrt{1-e^2}},$$

$$\frac{df}{de} = \left(\frac{a}{r} + \frac{1}{1-e^2} \right) \sin f,$$

$$\frac{dr}{de} = -a \cos f;$$

hence

$$\frac{d\Xi}{n dt} = -3a \left(\frac{d\Omega}{dg} \right),$$

$$\frac{dY}{n dt} = \frac{2}{e} \left[a \left(\frac{d\Omega}{dg} \right) - \frac{1}{\sqrt{1-e^2}} a \left(\frac{d\Omega}{df} \right) \right],$$

$$\frac{d\Psi}{n dt} = \frac{2}{\sqrt{1-e^2}} a \left(\frac{d\Omega}{de} \right).$$

Again from

$$\left(\frac{d\Omega}{dg} \right) = \left(\frac{d\Omega}{df} \right) \left(\frac{df}{dg} \right) + \left(\frac{d\Omega}{dr} \right) \left(\frac{dr}{dg} \right)$$

we have

$$\left(\frac{d\Omega}{df}\right) = \left(\frac{d\Omega}{dg}\right) \frac{r^2}{a^2 \sqrt{1-e^2}} - r \left(\frac{d\Omega}{dr}\right) \frac{r e \sin f}{a(1-e^2)}.$$

Eliminating $\left(\frac{d\Omega}{df}\right)$ from the expression for $\frac{dY}{ndt}$, we have

$$\frac{dY}{ndt} = \frac{2}{1-e^2} \left\{ \frac{a^2(1-e^2) - r^2}{a^2 e} a \left(\frac{d\Omega}{dg}\right) + \frac{r \sin f}{a \sqrt{1-e^2}} a r \left(\frac{d\Omega}{dr}\right) \right.$$

In the same way we find

$$\begin{aligned} \frac{dY}{ndt} = \frac{2}{1-e^2} \left\{ \left[\frac{r}{a} \sin f + \frac{r^2 \sin f}{a^2(1-e^2)} \right] a \left(\frac{d\Omega}{dg}\right) - \left[\frac{a \cos f}{r} \sqrt{1-e^2} + \frac{e \sin^2 f}{\sqrt{1-e^2}} \right. \right. \\ \left. \left. + \frac{r e \sin^2 f}{a(1-e^2)^{\frac{3}{2}}} \right] a r \left(\frac{d\Omega}{dr}\right) \right\} \end{aligned}$$

But if we employ the relation

$$1 = \frac{r}{a(1-e^2)} + \frac{r e \cos f}{a(1-e^2)}$$

in the term, $\frac{a \cos f}{r} \sqrt{1-e^2}$, of the preceding expression, the whole term becomes

$$-\left[\frac{r \cos f}{a(1-e^2)^{\frac{3}{2}}} + \frac{e}{\sqrt{1-e^2}} + \frac{r e}{a(1-e^2)^{\frac{3}{2}}} \right] a r \left(\frac{d\Omega}{dr}\right).$$

Using the equation

$$0 = -r e \cos f - r + a(1-e^2),$$

multiplying by

$$\frac{e}{a(1-e^2)^{\frac{3}{2}}} a r \left(\frac{d\Omega}{dr}\right),$$

adding to the preceding, it becomes

$$-\left[\frac{r \cos f}{a \sqrt{1-e^2}} + \frac{2e}{\sqrt{1-e^2}}\right] a r \left(\frac{d\Omega}{dr}\right).$$

Further, we have

$$\frac{d}{dg} \left[\frac{r}{a} \sin f + \frac{r^2 \sin f}{a^2 (1-e^2)} \right] = \frac{a}{r} \cos f \sqrt{1-e^2} + \frac{\cos f}{\sqrt{1-e^2}} + \frac{e \sin^2 f}{\sqrt{1-e^2}} + 2 \frac{r e \sin^2 f}{a (1-e^2)^{\frac{3}{2}}}.$$

Reducing this expression in the same manner as employed before, it becomes

$$\frac{d}{dg} \left[\frac{r}{a} \sin f + \frac{r^2 \sin f}{a^2 (1-e^2)} \right] = \frac{2 r \cos f + 3 a e}{a \sqrt{1-e^2}}.$$

Multiply this by dg , the last expression for $\frac{d\Psi}{ndt}$ becomes

$$\frac{d\Psi}{ndt} = \frac{2}{1-e^2} \left\{ \int \frac{2 r \cos f + 3 a e}{a \sqrt{1-e^2}} dg - a \left(\frac{d\Omega}{dg}\right) - \frac{r \cos f + 2 a e}{a \sqrt{1-e^2}} a r \left(\frac{d\Omega}{ar}\right) \right\},$$

the integral to be so taken that it vanishes at the same time with g .

Substituting these values of $\frac{d\Xi}{ndt}$, $\frac{dY}{ndt}$, $\frac{d\Psi}{ndt}$, in

$$\frac{dW}{ndt} = \frac{d\Xi}{ndt} + \frac{dY}{ndt} \left(\frac{\rho}{a} \cos \omega + \frac{3}{2} e \right) + \frac{d\Psi}{ndt} \frac{\rho}{a_i} \sin \omega,$$

this expression can be made to take the simple form

$$\frac{dW}{ndt} = A a \left(\frac{d\Omega}{dg}\right) + B a r \left(\frac{d\Omega}{dr}\right), \quad (31)$$

in which

$$A = -3 + \frac{1}{1-e^2} \left\{ \left(2 \frac{\rho}{a} \cos \omega + 3 e \right) \frac{a^2 (1-e^2) - r^2}{a^2 e} + \frac{2 \rho \sin \omega}{a \sqrt{1-e^2}} \int \left(\frac{2 r}{a} \cos f + 3 e \right) dg \right\}$$

$$B = \frac{1}{1-e^2} \left\{ \left(2 \frac{\rho}{a} \cos \omega + 3 e \right) \frac{r \sin f}{a \sqrt{1-e^2}} - \frac{2 \rho \sin \omega}{a \sqrt{1-e^2}} \left(\frac{r}{a} \cos f + 2 e \right) \right\}.$$

Since

$$\frac{d \cdot r^2}{a^2 e \cdot dg} = 2 \frac{r \sin f}{a(1-e^2)},$$

$$\frac{d \cdot r^2}{a^2 e \cdot de} = -2 \frac{r}{a} \cos f,$$

we have

$$A = -3 + \frac{1}{1-e^2} \left\{ \left[\frac{d \cdot \rho^2}{a^2 \cdot de} - 3e \right] \frac{r^2 - a^2(1-e^2)}{a^2 e} - \frac{d \cdot \rho^2}{a^2 e \cdot d\gamma} \int \left[\frac{d \cdot r^2}{a^2 \cdot de} - 3e \right] dg \right\}$$

$$B = \frac{1}{2(1-e^2)} \left\{ \frac{d \cdot \rho^2}{a^2 e \cdot d\gamma} \left[\frac{d \cdot r^2}{a^2 \cdot de} - 4e \right] - \left[\frac{d \cdot \rho^2}{a^2 \cdot de} - 3e \right] \frac{d \cdot r^2}{a^2 e \cdot dg} \right\}.$$

These expressions for A and B can be much simplified.

Thus from

$$\frac{r^2}{a^2} = 1 + \frac{3}{2} e^2 - (2e - \frac{1}{4} e^3) \cos g - (\frac{1}{2} e^2 - \frac{1}{6} e^4) \cos 2g - \frac{1}{4} e^3 \cos 3g - \frac{e^4}{6} \cos 4g - \text{etc.},$$

and a similar expression for $\frac{\rho^2}{a^2}$, we get

$$\frac{d \cdot \rho^2}{a^2 e \cdot d\gamma} = \left(2 - \frac{e^2}{4}\right) \sin \gamma,$$

$$\frac{d \cdot \rho^2}{a^2 \cdot de} - 3e = -(2 - \frac{3}{4} e^2) \cos \gamma,$$

$$\frac{d \cdot r^2}{a^2 e \cdot dg} = \left(2 - \frac{e^2}{4}\right) \sin g + \left(e - \frac{e^3}{3}\right) \sin 2g + \frac{3}{4} e^2 \sin 3g + \frac{2}{3} e^3 \sin 4g + \text{etc.},$$

$$\int \left[\frac{d \cdot r^2}{a^2 \cdot de} - 3e \right] dg = -(2 - \frac{3}{4} e^2) \sin g - \left(\frac{e}{2} - \frac{e^3}{3}\right) \sin 2g - \frac{e^2}{4} \sin 3g - \frac{e^3}{6} \sin 4g - \text{etc.},$$

$$\frac{r^2 - a^2(1-e^2)}{a^2 e} = \frac{5}{2} e - \left(2 - \frac{e^2}{4}\right) \cos g - \left(\frac{e}{2} - \frac{e^3}{6}\right) \cos 2g - \frac{e^2}{4} \cos 3g - \frac{e^3}{6} \cos 4g,$$

$$\frac{d \cdot r^2}{a^2 \cdot de} - 4e = -e - (2 - \frac{3}{4} e^2) \cos g - \left(e - \frac{2}{3} e^3\right) \cos 2g - \frac{3}{4} e^2 \cos 3g - \frac{2}{3} e^3 \cos 4g.$$

From which we obtain

$$\left. \begin{aligned}
 A &= -3 + (4 + 2e^2) \cos(\gamma - g) & B &= -(2 + e^2) \sin(\gamma - g) \\
 &+ \left(e + \frac{e^3}{4}\right) \cos(\gamma - 2g) && - \left(e + \frac{e^3}{4}\right) \sin(\gamma - 2g) \\
 &- \left(5e + \frac{25e^3}{8}\right) \cos \gamma && - \left(e + \frac{7e^3}{8}\right) \sin \gamma \\
 &+ \frac{e^2}{2} \cos(\gamma - 3g) && - \frac{3e^2}{4} \sin(\gamma - 3g) \\
 &+ \frac{e^3}{3} \cos(\gamma - 4g) && - \frac{2e^3}{3} \sin(\gamma - 4g) \\
 &+ \frac{e^3}{24} \cos(\gamma + 2g) && + \frac{e^3}{24} \sin(\gamma + 2g)
 \end{aligned} \right\} \quad (32)$$

These are the expressions of A and B whose values are used in the numerical computations.

When we have the coefficients of the arguments in which γ is $+1$, and -1 , we obtain the coefficients of the arguments in which γ is $\pm i$, with very little labor.

Let us resume the expression for $\frac{dW}{ndt}$, that is,

$$\frac{dW}{ndt} = A a \left(\frac{d\Omega}{dg}\right) + B ar \left(\frac{d\Omega}{dr}\right)$$

A and B having the values given before.

Since $\frac{r^2}{a^3}$ can be put in the form

$$\frac{r^2}{a^3} = \Sigma R^{(k)} \cos kg,$$

we have

$$\frac{2r \sin f}{a\sqrt{1-e^2}} = \frac{d\frac{r^2}{a^3}}{e dg} = -\Sigma \frac{k}{e} R^{(k)} \sin kg, \quad 2\frac{r}{a} \cos f = -\frac{d\frac{r^2}{a^3}}{de} = -\frac{dR^{(k)}}{de} \cos kg,$$

and

$$\int \left\{ \left(\frac{d \rho^2}{d e} \right) - 3 e \right\} d g = \frac{d R^{(k)}}{k d e} \sin k g + \frac{d R^{(0)}}{d e} g - 3 e g.$$

But since

$$\begin{aligned} \frac{\rho^2}{a^2} = 1 + \frac{3}{2} e^2 - (2e - \frac{1}{4} e^3 + \frac{1}{96} e^5) \cos g - (\frac{1}{2} e^2 - \frac{1}{6} e^4 + \frac{1}{48} e^6) \cos 2g \\ - (\frac{1}{4} e^3 - \frac{9}{64} e^5) \cos 3g - \text{etc.} \end{aligned}$$

we have

$$\frac{d R^{(0)}}{d e} = 3 e.$$

Hence the integral just given is simply $\frac{d R^{(k)}}{k d e} \sin k g$.

A and B can then be written

$$\begin{aligned} A = -3 + \frac{1}{1-e^2} \left[\left(2 \frac{\rho}{a} \cos \omega + 3e \right) \frac{a^2(1-e^2) - \rho^2}{a^2 e} - \frac{2 \rho \sin \omega}{a \sqrt{1-e^2}} \frac{d R^{(k)}}{k d e} \sin k g \right] \\ B = -\frac{1}{1-e^2} \left[\left(2 \frac{\rho}{a} \cos \omega + 3e \right) \frac{e}{2} k R^k \sin k g - \frac{2 \rho \sin \omega}{a \sqrt{1-e^2}} \left(\frac{d R^{(k)}}{d e} \cos k g - 2e \right) \right] \end{aligned}$$

Putting

$$\frac{\rho^2}{a^2} = \Sigma R^{(\kappa)} \cos \kappa \gamma,$$

we have likewise

$$2 \frac{\rho}{a} \cos \omega = - \frac{d \frac{\rho^2}{a^2}}{d e} = - \frac{d R^{(\kappa)}}{d e} \cos \kappa \gamma, \quad 2 \frac{\rho}{a} \sin \omega = \frac{d \frac{\rho^2}{a^2}}{e d \gamma} \sqrt{1-e^2} = - \frac{\kappa}{e} R^{(\kappa)} \sin \kappa \gamma.$$

Introducing these values of $2 \frac{\rho}{a} \cos \omega$, and $2 \frac{\rho}{a} \sin \omega$ into the expressions for A and B , after integration relative to γ we can write W in the form

$$W = \alpha^{(\kappa)} \frac{\sin}{\cos} (\kappa \gamma + \beta t),$$

where

$$\alpha^{(\kappa)} = \frac{dR^{(\kappa)}}{de} U + \kappa \frac{R^{(\kappa)}}{e} V$$

$$\beta t = ig + i'g',$$

U and V being two functions depending alone on t .

Putting $\kappa = +1$, and -1 , we have

$$\alpha^{(1)} = \frac{dR^{(1)}}{de} U + \frac{R^{(1)}}{e} V$$

$$\alpha^{(-1)} = \frac{dR^{(1)}}{de} U - \frac{R^{(1)}}{e} V;$$

and hence

$$U = \frac{\alpha^{(1)} + \alpha^{(-1)}}{2 \frac{dR^{(1)}}{de}}, \quad V = \frac{\alpha^{(1)} - \alpha^{(-1)}}{2 \frac{R^{(1)}}{e}}.$$

Thus we find

$$\alpha^{(\kappa)} = \frac{1}{2} \left[\frac{\frac{dR^{(\kappa)}}{de}}{\frac{dR^{(1)}}{de}} + \kappa \frac{R^{(\kappa)}}{R^{(1)}} \right] \alpha^{(1)} + \frac{1}{2} \left[\frac{\frac{dR^{(\kappa)}}{de}}{\frac{dR^{(1)}}{de}} - \kappa \frac{R^{(\kappa)}}{R^{(1)}} \right] \alpha^{(-1)};$$

or putting

$$\eta^{(\kappa)} = \frac{\frac{dR^{(\kappa)}}{de}}{2 \frac{dR^{(1)}}{de}} + \kappa \frac{R^{(\kappa)}}{2 R^{(1)}}$$

$$\theta^{(\kappa)} = \frac{\frac{dR^{(\kappa)}}{de}}{2 \frac{dR^{(1)}}{de}} - \kappa \frac{R^{(\kappa)}}{2 R^{(1)}},$$

we have

$$\alpha^{(\kappa)} = \eta^{(\kappa)} \alpha^{(1)} + \theta^{(\kappa)} \alpha^{(-1)}. \quad (33)$$

The values of $\eta^{(\kappa)}$ and $\theta^{(\kappa)}$ are readily found from

$$\begin{aligned} \frac{\rho^2}{a^2} &= 1 + \frac{3}{2} e^2 - (2e - \frac{1}{4} e^3 + \frac{1}{96} e^5) \cos \gamma - (\frac{1}{2} e^2 - \frac{1}{6} e^4 + \frac{1}{48} e^6) \cos 2\gamma \\ &\quad - (\frac{1}{4} e^3 - \frac{9}{64} e^5) \cos 3\gamma - \text{etc.} \\ &= \Sigma R^{(\kappa)} \cos \kappa \gamma. \end{aligned}$$

We have

$$\begin{aligned} R^{(0)} &= 1 + \frac{3}{2} e^2 \\ R^{(1)} &= -(2e - \frac{1}{4} e^3 + \frac{1}{96} e^5) \\ R^{(2)} &= -(\frac{1}{2} e^2 - \frac{1}{6} e^4 + \frac{1}{48} e^6) \\ R^{(3)} &= -(\frac{1}{4} e^3 - \frac{9}{64} e^5) \\ \text{etc.,} &= \text{etc.} \\ \frac{dR^{(0)}}{de} &= 3e \\ \frac{dR^{(1)}}{de} &= -(2 - \frac{3}{4} e^2 + \frac{5}{96} e^4) \\ \frac{dR^{(2)}}{de} &= -(e - \frac{2}{3} e^3 + \frac{1}{8} e^5) \\ \frac{dR^{(3)}}{de} &= -(\frac{3}{4} e^2 - \frac{45}{64} e^4) \\ \frac{dR^{(4)}}{de} &= -(\frac{2}{3} e^3 - \frac{4}{5} e^5) \\ \text{etc.,} &= \text{etc.} \end{aligned}$$

For $\eta^{(2)}$ we have

$$\eta^{(2)} = \frac{(e - \frac{2}{3} e^3 + \frac{1}{8} e^5)}{(4 - \frac{3}{2} e^2 + \frac{5}{48} e^4)} + \frac{(\frac{1}{2} e^2 - \frac{1}{6} e^4 + \frac{1}{48} e^6)}{(2e - \frac{1}{4} e^3 + \frac{1}{96} e^5)},$$

or

$$= (\frac{1}{4} e - \frac{7}{96} e^3 - \frac{1}{192} e^5) + (\frac{1}{4} e - \frac{5}{96} e^3 + \frac{1}{384} e^5);$$

$$\eta^{(2)} = \frac{1}{2} e - \frac{1}{8} e^3 - \frac{1}{384} e^5. \quad (34)$$

For $\theta^{(2)}$ we get at once

$$\theta^{(2)} = -\frac{1}{48} e^3 - \frac{1}{128} e^5.$$

In a similar way we have

$$\eta^{(3)} = \frac{3}{8} e^2 - \frac{15}{128} e^4, \quad \eta^{(4)} = \frac{1}{3} e^3. \quad (35)$$

In case of the third coördinate we also compute the coefficients of the arguments having no angle γ from those having $\pm \gamma$. For this purpose, putting $\kappa = 0$ in the expression for $\alpha^{(\kappa)}$ we have

$$\alpha^{(0)} = \frac{dR^{(0)}}{de} U = \frac{dR^{(0)}}{de} \frac{a^{(1)} + a^{(-1)}}{2 \frac{dR^{(1)}}{de}} = \eta^{(0)} (a^{(1)} + a^{(-1)}),$$

where

$$\eta^{(0)} = \frac{\frac{dR^{(0)}}{de}}{2 \frac{dR^{(1)}}{de}}.$$

For $\eta^{(0)}$ we then have

$$\eta^{(0)} = -\left(\frac{3}{2} e + \frac{9}{16} e^3 \pm \text{etc.}\right). \quad (36)$$

Perturbation of the Third Coördinate.

Let b the angle between the radius-vector and the fundamental plane,
 i the inclination of the plane of the orbit to the fundamental plane,
 $v - \sigma$ the angular distance from the ascending node to the radius-vector.

We have then

$$\sin b = \sin i \sin (v - \sigma).$$

If we use for i and σ their values for the epoch and call them i_0 and \oslash_0 , \oslash_0 being the longitude of the ascending node, we have

$$\sin b = \sin i_0 \sin (v - \oslash_0) + s;$$

s is the perturbation.

Thus we find

$$s = \sin i \sin (v - \sigma) - \sin i_0 \sin (v - \oslash_0).$$

Putting

$$p = \sin i \sin (\sigma - \odot_0), \quad q = \sin i \cos (\sigma - \odot_0) - \sin i_0,$$

we find

$$s = q \sin (v - \odot_0) - p \cos (v - \odot_0).$$

Instead of s , let us use

$$u = \frac{r}{a_0} s,$$

and we have

$$u = \frac{r}{a_0} q \sin (v - \odot_0) - \frac{r}{a_0} p \cos (v - \odot_0).$$

Introducing τ and calling R the new function taking the place of u , we have, putting $\omega + \pi_0$ for v , π_0 being the longitude of the perihelion,

$$\frac{dR}{dt} = \frac{dq}{dt} \frac{\rho}{a_0} \sin (\omega + \pi_0 - \odot_0) - \frac{dp}{dt} \frac{\rho}{a_0} \cos (\omega + \pi_0 - \odot_0).$$

To find $\frac{dq}{dt}$ and $\frac{dp}{dt}$ we will employ the method given by WATSON in the eighth chapter of his *Theoretical Astronomy*.

Thus α and β being direction cosines we have

$$z_1 = \alpha x + \beta y;$$

also

$$z_1 = r \sin i \sin (v - \sigma).$$

But

$$r = r \cos v, \text{ and } y = r \sin v.$$

Hence

$$z_1 = -x \sin i \sin \sigma + y \sin i \cos \sigma;$$

and

$$\alpha = -\sin i \sin \sigma, \quad \beta = \sin i \cos \sigma.$$

The values of p and q then are given by the equations

$$p = -\alpha \cos \varpi_0 - \beta \sin \varpi_0,$$

$$q = -\alpha \sin \varpi_0 + \beta \cos \varpi_0 - \sin i_0;$$

from which we have

$$\frac{dp}{dt} = -\cos \varpi_0 \frac{d\alpha}{dt} - \sin \varpi_0 \frac{d\beta}{dt},$$

$$\frac{dq}{dt} = -\sin \varpi_0 \frac{d\alpha}{dt} + \cos \varpi_0 \frac{d\beta}{dt}.$$

From the equation $z_1 = \alpha x + \beta y$ we have, first regarding α and β as constant, then regarding x and y as constant,

$$\left(\frac{dz_1}{dt}\right) = \alpha \frac{dx}{dt} + \beta \frac{dy}{dt}$$

$$\left[\frac{dz_1}{dt}\right] = x \frac{d\alpha}{dt} + y \frac{d\beta}{dt} = 0.$$

Differentiating the first of these, regarding all the quantities variable, we have

$$\frac{d^2 z_1}{dt^2} = \frac{d\alpha}{dt} \frac{dx}{dt} + \frac{d\beta}{dt} \frac{dy}{dt} + \alpha \frac{d^2 x}{dt^2} + \beta \frac{d^2 y}{dt^2}.$$

Z_1 being the component of the disturbing force parallel to the axis z_1 , and X and Y the other two components, we have

$$Z_1 = \alpha X + \beta Y + Z \cos i.$$

Writing for X and Y their values

$$\frac{d^2 x}{dt^2} + k^2 (1+m) \frac{x}{r^3}, \quad \frac{d^2 y}{dt^2} + k^2 (1+m) \frac{y}{r^3},$$

and reducing by means of

$$z_1 = \alpha x + \beta y,$$

we have

$$Z_1 = \alpha \frac{d^2 x}{dt^2} + \beta \frac{d^2 y}{dt^2} + k^2 (1 + m) \frac{z_1}{r^3} + Z \cos i,$$

or

$$\frac{d^2 z_1}{dt^2} = \alpha \frac{d^2 x}{dt^2} + \beta \frac{d^2 y}{dt^2} + Z \cos i.$$

Comparing this with the other expression for $\frac{d^2 z_1}{dt^2}$, given above,

we have

$$\frac{d\alpha}{dt} \frac{dx}{dt} + \frac{d\beta}{dt} \frac{dy}{dt} = Z \cos i.$$

From this equation, and the value of $\left[\frac{dz_1}{dt}\right]$, since

$$x \frac{dy}{dt} - y \frac{dx}{dt} = k \sqrt{p(1+m)} = \frac{1}{h},$$

we find

$$\frac{d\alpha}{dt} = -h r \cos i \sin v Z,$$

$$\frac{d\beta}{dt} = h r \cos i \cos v Z.$$

Substituting these values in the expressions for $\frac{dp}{dt}$ and $\frac{dq}{dt}$,

we have

$$\frac{dp}{dt} = h r \cos i \sin (v - \infty_0) Z,$$

$$\frac{dq}{dt} = h r \cos i \cos (v - \infty_0) Z.$$

Introducing these values into the expression for $\frac{dR}{dt}$

we have

$$\begin{aligned}\frac{dR}{dt} &= h r \cos i \cos (v - \varpi_0) \frac{\rho}{a_0} \sin (\omega + \pi_0 - \varpi_0) Z \\ &\quad - h r \cos i \sin (v - \varpi_0) \frac{\rho}{a_0} \cos (\omega + \pi_0 - \varpi_0) Z \\ &= h r \cos i \frac{\rho}{a_0} \left[\sin \omega \cos (v - \varpi_0 - (\pi_0 - \varpi_0)) \right] Z \\ &\quad - h r \cos i \frac{\rho}{a_0} \left[\cos \omega \sin (v - \varpi_0 - (\pi_0 - \varpi_0)) \right] Z \\ &= h r \cos i \frac{\rho}{a_0} \sin (\omega - f) \frac{d\Omega}{dZ}.\end{aligned}$$

Introducing $n = \frac{k\sqrt{1+m}}{a^{\frac{3}{2}}}$, and $h = \frac{k\sqrt{1+m}}{\sqrt{p}}$,

we have

$$\frac{dR}{ndt} = \frac{1}{\sqrt{1-e^2}} \frac{r}{a} \frac{\rho}{a_0} \sin (\omega - f) a^2 \frac{d\Omega}{dZ} \cos i. \quad (37)$$

Let

$$C = \frac{1}{\sqrt{1-e^2}} \frac{r}{a} \frac{\rho}{a_0} \sin (\omega - f);$$

then

$$\frac{dR}{\cos i \cdot ndt} = C \cdot a^2 \left(\frac{d\Omega}{dZ} \right).$$

To find an expression for C similar to those for A and B we have, first,

$$C = \frac{1}{\sqrt{1-e^2}} \left[\frac{\rho}{a_0} \sin \omega \cdot \frac{r}{a} \cos f - \frac{\rho}{a_0} \cos \omega \cdot \frac{r}{a} \sin f \right].$$

Substituting the values of $\frac{r}{a} \cos f$, $\frac{r}{a} \sin f$, given before, and similar ones for $\frac{p}{a_0} \cos \omega$, $\frac{p}{a_0} \sin \omega$, we find

$$C = \frac{1}{4} \left(\frac{d.\rho^2}{a_0^2 de} \right) \left(\frac{d.r^2}{a^2 edg} \right) - \frac{1}{4} \left(\frac{d.\rho^2}{a_0^2 edg} \right) \left(\frac{d.r^2}{a^2 de} \right).$$

Substituting the values of these factors we obtain for C the expression

$$C = \left(\begin{aligned} & (1 - \frac{1}{2} e^2) \sin (\gamma - g) \\ & - (\frac{3}{2} e - \frac{3}{16} e^3) \sin \gamma \\ & + (\frac{1}{2} e - \frac{3}{8} e^3) \sin (\gamma - 2g) \\ & + \frac{3}{8} e^2 \sin (\gamma - 3g) \\ & + \frac{1}{3} e^3 \sin (\gamma - 4g) \\ & - \frac{1}{48} e^3 \sin (\gamma + 2g) \end{aligned} \right) \quad (38)$$

Having found the expressions for $\frac{dW}{ndt}$ and $\frac{du}{ndt \cdot \cos i}$

we have, finally, for determining the perturbations, the following expressions :

$$n\delta z = n \int \bar{W} dt,$$

$$v = - \frac{1}{2} n \int \frac{dW}{d\gamma} dt,$$

$$\frac{''}{\cos i} = \int C a^2 \left(\frac{d\Omega}{dZ} \right) .$$

Two integrations are needed to find $n\delta z$. We first find W from $\frac{dW}{ndt}$; then, forming \bar{W} and $-\frac{1}{2} \frac{d\bar{W}}{d\gamma}$ from W we have $n\delta z$ and v by integrating these quantities. In the integration of $\frac{dW}{ndt}$ we give to the constants of integration the form

$$k_0 + k_1 \cos \gamma + k_2 \sin \gamma + \eta^{(2)} k_1 \cos 2\gamma + \eta^{(2)} k_2 \sin 2\gamma + \text{etc.}$$

Then in case of $-\frac{1}{2} \frac{dW}{d\gamma}$ we have

$$+\frac{1}{2} k_1 \sin \gamma - \frac{1}{2} k_2 \cos \gamma + \eta^{(2)} k_1 \sin 2\gamma - \eta^{(2)} k_2 \cos 2\gamma + \text{etc.}$$

In the second integration we call the two new constants C and N , and the constants of the results are in the forms

$$C + k_0 nt + k_1 \sin g - k_2 \cos g + \frac{1}{2} \eta^{(2)} k_1 \sin 2g - \frac{1}{2} \eta^{(2)} k_2 \cos 2g \pm \text{etc.}$$

$$N - \frac{1}{2} k_1 \cos g - \frac{1}{2} k_2 \sin g - \frac{1}{2} \eta^{(2)} k_1 \cos 2g - \frac{1}{2} \eta^{(2)} k_2 \sin 2g - \text{etc.}$$

In case of the latitude the constants are given in the form

$$l_0 + l_1 \sin g + l_2 \cos g + \eta^{(2)} l_1 \sin 2g + \eta^{(2)} l_2 \cos 2g + \text{etc.}$$

The constants are so determined that the perturbations become zero for the epoch of the elements. Hence also the first differential coefficients of the perturbations relative to the time are zero. We substitute the values of g and g' at the epoch in the expressions for $n\delta z$, ν , $\frac{u}{\cos i}$, $\frac{d}{ndt}(n\delta z)$, etc., including in g' the long period term. Putting the constants equal to zero, and designating the values of $n\delta z$, ν , etc., at the epoch by a subscript zero, we have the following equations for determining the values of the constants of integration:

$$C + k_1 \sin g - k_2 \cos g + \frac{1}{2} \eta^{(2)} k_1 \sin 2g - \frac{1}{2} \eta^{(2)} k_2 \cos 2g + \text{etc.} + (n\delta z)_0 = g_0$$

$$k_0 + k_1 \cos g + k_2 \sin g + \eta^{(2)} k_1 \cos 2g + \eta^{(2)} k_2 \sin 2g + \text{etc.} + \frac{d}{ndt}(n\delta z)_0 = 0$$

$$N - \frac{1}{2} k_1 \cos g - \frac{1}{2} k_2 \sin g - \frac{1}{2} \eta^{(2)} k_1 \cos 2g - \frac{1}{2} \eta^{(2)} k_2 \sin 2g - \text{etc.} + (\nu)_0 = 0$$

$$+\frac{1}{2} k_1 \sin g - \frac{1}{2} k_2 \cos g + \eta^{(2)} k_1 \sin 2g - \eta^{(2)} k_2 \cos 2g + \text{etc.} + \frac{d}{ndt}(\nu)_0 = 0$$

$$l_0 + l_1 \sin g + l_2 \cos g + \eta^{(2)} l_1 \sin 2g + \eta^{(2)} l_2 \cos 2g + \text{etc.} + \left(\frac{u}{\cos i}\right)_0 = 0$$

$$l_1 \cos g - l_2 \sin g + \eta^{(2)} l_1 \cos 2g - \eta^{(2)} l_2 \sin 2g + \text{etc.} + \frac{d}{ndt}\left(\frac{u}{\cos i}\right)_0 = 0$$

To find k_1 and k_2 , we derive from the preceding

$$\begin{aligned}
 k_1 \left[\cos g - e + \eta^{(2)} \cos 2g + \eta^{(3)} \cos 3g + \text{etc.} \right] + k_2 \left[\sin g + \eta^{(2)} \sin 2g + \text{etc.} \right] \\
 - 3Z_0 + 6(\nu)_0 + 4 \frac{d}{ndt} (n\delta z)_0 = 0 \\
 k_1 \left[\sin g + 2\eta^{(2)} \sin 2g + 3\eta^{(3)} \sin 3g + \text{etc.} \right] - k_2 \left[\cos g + 2\eta^{(2)} \cos 2g + \text{etc.} \right] \\
 + 2 \frac{d}{ndt} (\nu)_0 = 0
 \end{aligned}$$

The value of N is found further on.

Having k_1 we find k_0 from

$$-k_0 - e k_1 - 3Z_0 + 3 \frac{d}{ndt} (n\delta z)_0 + 6(\nu)_0 = 0.$$

We have

$$l_0 = -e l_2, N = -\frac{2}{3} k_0 - \frac{e}{6} k_1 - \frac{1}{2} Z_0,$$

where Z_0 is the constant of W .

Let us find the expressions for the constants N and K , K being the constant of integration in the expression for $\delta \frac{h}{h_0}$.

The equation (22) we can put in the form

$$\frac{dz}{dt} = \frac{h_0}{h} - 2\nu + (3\nu^2 - 4\nu^3 \pm \text{etc.}) \frac{h_0}{h} - 2\nu \left(\frac{h_0}{h} - 1 \right).$$

The differentiation of nz relative to the time gives

$$\frac{dz}{dt} = 1 + k_0 + Z_0 + Z_1 + \text{periodic terms},$$

where $Z_0 = -32''.7162$, in the case of Althæa, and Z_1 the part to be added when terms of the second order of the disturbing force are taken into account.

The expression for ν is

$$\nu = N + \text{periodic terms.}$$

The approximate value of $\frac{h_0}{h}$ being 1, the complete expression for the integral of $d \frac{h_0}{h}$ is given by

$$\frac{h_0}{h} = 1 + k_3 + \text{periodic terms,}$$

k_3 being the constant of integration.

Putting $(3\nu^2 - 4\nu^3 + \text{etc.}) \frac{h_0}{h} - 2\nu \left(\frac{h_0}{h} - 1 \right) = V_1 + \text{periodic terms}$, and substituting this expression, together with those of ν and $\frac{h_0}{h}$, in the expression for $\frac{dz}{dt}$, we have, preserving only the constant terms,

$$N = \frac{1}{2} (k_3 - k_0 - Z_0 - Z_1 + V_1).$$

It is necessary now to find the value of k_3 in terms of the constants. If in the expression for $\frac{dW_0}{dt}$ given by equation (18) we write for ρ , its equivalent $a_0 \cos^2 \phi_0 - e_0 \rho \cos \omega$, we will have

$$\begin{aligned} dW_0 = h_0 \left\{ 2 \frac{\rho}{r} \cos(f - \omega) - 1 - 2 \frac{h^2}{h_0^2} + 2 \frac{h^2}{h_0^2} \frac{\rho \cos(f - \omega)}{a_0 \cos^2 \phi_0} + 2e_0 \frac{h^2}{h_0^2} \frac{\rho \cos \omega}{a_0 \cos^2 \phi_0} \right\} \left(\frac{d\Omega}{df} \right) dt \\ + 2h_0 \rho \sin(f - \omega) \left(\frac{d\Omega}{dr} \right) dt. \end{aligned}$$

We also have

$$d \frac{h_0}{h} = h_0 \left(\frac{d\Omega}{df} \right) dt.$$

Selecting from the expression for dW_0 the terms not containing $\rho \cos \omega$ and $\rho \sin \omega$, we have

$$dW_0 = -h_0 \left(1 + 2 \frac{h^2}{h_0^2} \right) \left(\frac{d\Omega}{df} \right) dt.$$

If the eccentric anomaly is taken as the independent variable we have for the complete integral

$$W_0 = k_0 + k_1 \cos \eta + k_2 \sin \eta - h_0 \int \left(1 + 2 \frac{h^2}{h_0^2}\right) \left(\frac{d\Omega}{df}\right) dt.$$

Introducing the true anomaly instead of the eccentric, we have,

since
$$\cos \eta = \frac{\cos \omega + e}{1 + e \cos \omega}, \quad \sin \eta = \frac{\sin \omega \cos \varphi_0}{1 + e \cos \omega},$$

$$W_0 = k_0 + e_0 k_1 + \frac{k_1}{a_0} \rho \cos \omega + \frac{k_2}{a_0 \cos \varphi_0} \rho \sin \omega - h_0 \int \left(1 + 2 \frac{h^2}{h_0^2}\right) \left(\frac{d\Omega}{df}\right) dt.$$

Neglecting the terms having $\rho \cos \omega$ and $\rho \sin \omega$ we have in W_0 the constants k_0 and $e_0 k_1$.

The integral of $d \frac{h_0}{h}$ is

$$\frac{h_0}{h} = 1 + k_3 + h_0 \int \left(\frac{d\Omega}{df}\right) dt.$$

From the expression for $d \frac{h_0}{h}$ we find

$$d \frac{h}{h_0} = - \frac{h^2}{h_0} \left(\frac{d\Omega}{df}\right) dt.$$

Integrating this, making use of the value of $\frac{h_0}{h}$, and adding the constants, we have

$$2 \frac{h}{h_0} - \frac{h_0}{h} = 1 + k_0 + e k_1 - h_0 \int \left(1 + 2 \frac{h^2}{h_0^2}\right) \left(\frac{d\Omega}{df}\right) dt.$$

And since the quantities under the sign of integration do not have any constant terms we can write

$$2 \frac{h}{h_0} - \frac{h_0}{h} = 1 + k_0 + e k_1 + \text{periodic terms}$$

$$\frac{h_0}{h} = 1 + k_3 + \text{periodic terms}$$

Since $\left(\frac{h_0}{h} - 1\right)$ is a quantity of the order of the disturbing force we have

$$\frac{h}{h_0} = 1 - \left(\frac{h_0}{h} - 1\right) + \left(\frac{h_0}{h} - 1\right)^2 - \left(\frac{h_0}{h} - 1\right)^3 \pm \text{etc.},$$

from which we get

$$2 \frac{h}{h_0} - \frac{h_0}{h} = 4 - 3 \frac{h_0}{h} + 2 \left(\frac{h_0}{h} - 1\right)^2 - 2 \left(\frac{h_0}{h} - 1\right)^3 \pm \text{etc.}$$

Now putting

$$\left(\frac{h_0}{h} - 1\right)^2 - \left(\frac{h_0}{h} - 1\right)^3 \pm \text{etc.} = H_1 + \text{periodic terms},$$

substituting this expression and those for

$$2 \frac{h}{h_0} - \frac{h_0}{h}, \quad \frac{h_0}{h},$$

the preceding expression for

$$2 \frac{h}{h_0} - \frac{h_0}{h}$$

gives, preserving only constant terms,

$$k_3 = -\frac{1}{3}(k_0 + ek_1) + \frac{2}{3}H_1.$$

Introducing this value of k_3 into the expression for N it becomes

$$N = -\frac{1}{6}(4k_0 + ek_1 + 3Z_0) + \frac{1}{6}(3V_1 + 2H_1 - 3Z_1).$$

Preserving only the terms of the first order we have

$$N = -\frac{1}{6}(4k_0 + ek_1 + 3Z_0).$$

To find the value of K , the constant of integration in case of $\delta \frac{h}{h_0}$, we have

$$\frac{h}{h_0} = 1 + K + \text{periodic terms},$$

also

$$\frac{h_0}{h} = 1 + k_3 + \text{periodic terms.}$$

From these we get

$$\frac{h}{h_0} - 1 + \frac{h_0}{h} - 1 = K + k_3 = H_1.$$

Hence

$$K = -k_3 + H_1 = \frac{1}{3}(k_0 + ek_1) + \frac{1}{3}H_1;$$

or, neglecting the term of the second order,

$$K = \frac{1}{3}(k_0 + ek_1).$$

CHAPTER V.

*Numerical Example Giving the Principal Formulæ Needed in the Computation
Together with Directions for their Application.*

ALTHÆA 119.

$$\begin{aligned} g &= 332^\circ 48' 53''.2 \\ \pi &= 11 \quad 54 \quad 21.1 \\ \oslash &= 203 \quad 51 \quad 51.5 \\ i &= 5 \quad 44 \quad 4.6 \\ \phi &= 4 \quad 36 \quad 24.9 \\ n &= 855''.76428 \end{aligned} \left. \vphantom{\begin{aligned} g \\ \pi \\ \oslash \\ i \\ \phi \\ n \end{aligned}} \right\} 1894.0$$

$$\log n = 2.9323542$$

$$\log a = 0.4117683$$

JUPITER.

$$\begin{aligned} g' &= 63 \quad 5 \quad 48.6 \\ \pi' &= 12 \quad 36 \quad 59.4 \\ \oslash' &= 99 \quad 22 \quad 59.9 \\ i' &= 1 \quad 18 \quad 36.9 \\ \phi' &= 2 \quad 45 \quad 57.2 \\ n' &= 299''.12834 \end{aligned} \left. \vphantom{\begin{aligned} g' \\ \pi' \\ \oslash' \\ i' \\ \phi' \\ n' \end{aligned}} \right\} 1894.0$$

$$\log n' = 2.4758576$$

$$\log a' = 0.7162374$$

The epoch is 1894 Aug. 23.0.

The elements of Jupiter are those given by HILL in his *New Theory of Jupiter and Saturn*, in which the epoch is 1850.0. Applying the annual motion of $57''.9032$ in π' , of $36''.36617$ in \oslash' , to HILL'S value of π' , and of \oslash' , we have the values given above. The mass of Jupiter is $\frac{1}{1047.879}$. The elements of Althæa are those given in the *Berliner Astronomisches Jahrbuch* for 1896. The ecliptic and mean equinox are for 1890. To reduce from 1890 to 1894 we employ the formulæ of WATSON in his *Theoretical Astronomy*, pp. 100-102.

$$i' = i + \eta \cos (\oslash - \theta)$$

$$\oslash' = \oslash + (t' - t) \frac{dl}{dt} - \eta \sin (\oslash - \theta) \cot i'$$

$$\pi' = \pi + (t' - t) \frac{dl}{dt} + \eta \sin (\oslash - \theta) \tan \frac{1}{2} i'$$

where

$$\theta = 351^{\circ} 36' 10'' + 39''.79 (t - 1750) - 5''.21 (t' - t)$$

$$\eta = 0''.468 (t' - t)$$

$$\frac{dl}{dt} = 50''.246.$$

These expressions for i' , ϖ' and π' , can be used for the disturbed body as well as for the disturbing body by considering the unaccented quantities to be those given, and the accented quantities those whose values are to be found for the time, t' . HARKNESS, in his work, *The Solar Parallax and Its Related Constants*, using the most recent data, gives the following expressions for θ , η , and $\frac{dl}{dt}$, when referred to 1850.0:

$$\theta = 353^{\circ} 34' 55'' + 32''.655 (t - 1850) - 8''.79 (t' - t),$$

$$\eta = 0''.46654 (t - 1850),$$

$$\frac{dl}{dt} = [50''.23622 + 0''.000220 (t - 1850)] (t' - t).$$

$$\text{Let } \mu = \frac{n}{n'},$$

we have then

$$\mu = 0.34955$$

$$2\mu = 0.69910$$

$$3\mu = 1.04865$$

$$4\mu = 1.39820$$

$$5\mu = 1.74775$$

$$6\mu = 2.09730$$

$$\text{etc.} = \text{etc.}$$

Hence

$$1 - 3\mu = -.04865,$$

$$2 - 6\mu = -.09730.$$

This shows that the arguments $(g - 3g')$, and $(2g - 6g')$, have coefficients in the final expressions for the perturbations greatly affected by the factors of integration. In case of the argument $(g - 3g')$, we should compute the coefficients with more decimals; also those of $(0 - 3g')$ and $(2g - 3g')$, since in the developments the coefficients of these affect those of $(g - 3g')$.

From

$$\sin \frac{1}{2} I. \sin \frac{1}{2} (\Psi + \Phi) = \sin \frac{1}{2} (\oslash - \oslash') \sin \frac{1}{2} (i - i')$$

$$\sin \frac{1}{2} I. \cos \frac{1}{2} (\Psi + \Phi) = \cos \frac{1}{2} (\oslash - \oslash') \sin \frac{1}{2} (i - i')$$

$$\cos \frac{1}{2} I. \sin \frac{1}{2} (\Psi - \Phi) = \sin \frac{1}{2} (\oslash - \oslash') \cos \frac{1}{2} (i + i')$$

$$\cos \frac{1}{2} I. \cos \frac{1}{2} (\Psi - \Phi) = \cos \frac{1}{2} (\oslash - \oslash') \cos \frac{1}{2} (i + i')$$

where, if $\oslash' > \oslash$, we take $\frac{1}{2} (360^\circ + \oslash - \oslash')$, instead of $\frac{1}{2} (\oslash - \oslash')$, we find

$$\begin{array}{r} \Psi = 116^\circ \quad 15' \quad 36.7 \end{array}$$

$$\Phi = \quad 11 \quad 50 \quad 33.9$$

$$I = \quad 6 \quad 11 \quad 35.3$$

An independent determination of these quantities is found from the equations

$$\cos p \sin q = \sin i' \cos (\oslash - \oslash')$$

$$\cos p \cos q = \cos i'$$

$$\cos p \sin r = \cos i' \sin (\oslash - \oslash')$$

$$\cos p \cos r = \cos (\oslash - \oslash')$$

$$\sin p = \sin i' \sin (\oslash - \oslash')$$

$$\sin I \sin \Phi = \sin p$$

$$\sin I \cos \Phi = \cos p \sin (i - q)$$

$$\sin I \sin (\Psi - r) = \sin p \cos (i - q)$$

$$\sin I \cos (\Psi - r) = \cos p \sin (i - q)$$

$$\cos I = \cos p \cos (i - q).$$

From

$$\Pi = \pi - \varpi - \Phi$$

$$\Pi' = \pi' - \varpi' - \Psi$$

we have

$$\Pi = 156^\circ 11' 55''.7, \Pi' = 156^\circ 58' 22''.8.$$

Then from

$$k \sin K = \cos I \sin \Pi'$$

$$k \cos K = \cos \Pi'$$

$$k_1 \sin K_1 = \sin \Pi'$$

$$k_1 \cos K_1 = \cos I \cos \Pi'$$

$$p \sin P = 2\alpha^2 \frac{e'}{e} - 2\alpha k \cos (\Pi - K)$$

$$p \cos P = 2\alpha \cos \phi' k_1 \sin (\Pi - K_1)$$

$$v \sin V = 2\alpha \cos \phi k \sin (\Pi - K)$$

$$v \cos V = 2\alpha \cos \phi \cos \phi' k_1 \cos (\Pi - K_1)$$

$$w \sin W = p - 2\alpha^2 \frac{e'}{e} \sin P$$

$$w \cos W = v \cos (V - P)$$

$$w_1 \sin W_1 = v \sin (V - P)$$

$$w_1 \cos W_1 = 2\alpha^2 \frac{e'}{e} \cos P,$$

we find

$K = 157^\circ$	5'	36''.6	$\log k = 9.999614$
$K_1 = 156$	51	7.4	$\log k_1 = 9.997849$
$P = 93$	3	27.0	$\log p = 9.932748$
$V = 359$	6	2.4	$\log v = 0.601463$
$W = 266$	4	39.5	$\log w = 0.605196$
$W_1 = 266$	15	38.0	$\log w_1 = 0.601352$

Then from

$$R = 1 + \alpha^2 - 2\alpha^2 e'^2, \quad \gamma_2 = \alpha^2 e'^2,$$

we have

$$\log R = 0.702855, \quad \log \gamma_2 = 7.976024.$$

The values of the quantities from Π to γ_2 should be found by a duplicate computation without reference to the former computation, since any error in these quantities will affect all that follows.

We now divide the circumference into sixteen parts relative to the mean anomaly, and find the corresponding values of the eccentric anomaly E from

$$g = E - e \sin E,$$

where e is regarded as expressed in seconds of arc. Substituting the sixteen values of e in the equations

$$f \sin (F - P) = w \sin (E - W) - e p$$

$$f \cos (F - P) = w_1 \cos (E + W_1),$$

we obtain the corresponding values of f and F .

Then in a similar manner from

$$Q = F + x$$

$$C = \gamma_0 + \gamma_2 \sin^2 Q$$

$$\log q = \log f + y$$

$$x = s \left(\frac{\gamma_0 \gamma_2}{f^2} + \frac{\gamma_2^2}{2f^2} \right) \sin 2F + s \left(\frac{3\gamma_0^2 \gamma_2^2}{2f^4} - \frac{\gamma_2^2}{4f^2} \right) \sin 4F$$

$$y = \lambda_0 \frac{\gamma_2^2}{4f^2} - \lambda_0 \left(\frac{\gamma_0 \gamma_2}{f^2} + \frac{\gamma_2^2}{2f^2} \right) \cos 2F - \lambda_0 \left(\frac{3\gamma_0^2 \gamma_2^2}{2f^4} - \frac{\gamma_2^2}{4f^2} \right) \cos 4F,$$

$$\text{where } s = 206264''.8, \quad \log \lambda_0 = 9.63778,$$

we find the values of Q , C , $\log q$, x , and y .

Thus we have found all the quantities entering into the expression

$$\left(\frac{d}{a} \right)^2 = (C - q \cos(E' - Q)) \left(1 - \frac{\gamma_2}{q} \cos(E' + Q) \right).$$

Instead of this, we use the transformed expression

$$\left(\frac{a}{d} \right)^n = N^n (1 + a^2 - 2a \cos(E' - Q))^{-\frac{n}{2}} (1 + b^2 - 2b \cos(E' + Q))^{-\frac{n}{2}},$$

and have, for finding the values of N , a , b^2 , the equations

$$\frac{q}{C} = \sin \chi$$

$$\frac{\gamma_2}{q} = \sin \chi_1$$

$$a = tg \frac{1}{2} \chi$$

$$b = tg \frac{1}{2} \chi_1$$

$$N = \frac{\sec \frac{1}{2} \chi \sec \frac{1}{2} \chi_1}{\sqrt{C}}.$$

To find the value of $\left(\frac{a}{d}\right)^n$ we put

$$(1 + a^2 - 2a \cos (E' - Q))^{-\frac{n}{2}} = \left[\frac{1}{2} b_{\frac{n}{2}}^{(0)} + b_{\frac{n}{2}}^{(1)} \cos (E' - Q) + b_{\frac{n}{2}}^{(2)} \cos 2(E' - Q) + \text{etc.} \right]$$

$$(1 + b^2 - 2b \cos (E' + Q))^{-\frac{n}{2}} = \left[\frac{1}{2} B_{\frac{n}{2}}^{(0)} + B_{\frac{n}{2}}^{(1)} \cos (E' + Q) + B_{\frac{n}{2}}^{(2)} \cos 2(E' + Q) \right. \\ \left. + \text{etc.} \right]$$

For finding the values of the coefficients in these expressions we use RUNKLE'S *Tables for Determining the Values of the Coefficients in the Perturbative Function of Planetary Motion*, published by the Smithsonian Institution. With the sixteen values of a as arguments we enter these tables and find at once the corresponding values of $b_{\frac{1}{2}}^{(0)}$, then those of $\frac{b_{\frac{1}{2}}^{(1)}}{a}$, $\frac{b_{\frac{1}{2}}^{(2)}}{a^2}$, $\frac{b_{\frac{1}{2}}^{(3)}}{a^3}$, etc., etc.; $\frac{a^4}{\beta^4} \cdot b_{\frac{3}{2}}^{(0)}$, $\frac{a^3}{\beta^4} \cdot b_{\frac{3}{2}}^{(1)}$, $\frac{a^2}{\beta^4} \cdot b_{\frac{3}{2}}^{(2)}$, etc., etc., where β^4 is found from the sixteen values of $\beta^2 = \frac{a^2}{1-a^2}$.

Since b in $(1 - 2b \cos (E' + Q))$ is very small it will suffice to put

$$\frac{1}{2} B_{\frac{n}{2}}^{(0)} = 1, \quad B_{\frac{1}{2}}^{(1)} = b \\ B_{\frac{3}{2}}^{(1)} = 3b, \quad B_{\frac{5}{2}}^{(1)} = 5b.$$

Then from

$$c_{\frac{n}{2}}^{(i)} = \frac{1}{2} N^n B_{\frac{n}{2}}^{(i)} \cos 2iQ \\ s_{\frac{n}{2}}^{(i)} = \frac{1}{2} N^n B_{\frac{n}{2}}^{(i)} \sin 2iQ,$$

we have, in case of $\mu \left(\frac{a}{d}\right)$,

$$\frac{1}{8} c_{\frac{1}{2}}^{(0)} = \frac{1}{8} N, \quad \frac{1}{8} c_{\frac{1}{2}}^{(1)} = \frac{1}{16} N b \cos 2Q, \quad \frac{1}{8} s_{\frac{1}{2}}^{(1)} = \frac{1}{16} N b \sin 2Q;$$

and, for $\mu\alpha^2 \left(\frac{a}{\Delta}\right)^3$,

$$\frac{1}{8} c_2^{(0)} = \frac{1}{8} N^3, \quad \frac{1}{8} c_2^{(1)} = \frac{1}{16} N^3 3b \cos 2Q, \quad \frac{1}{8} s_2^{(1)} = \frac{1}{16} N^3 3b \sin 2Q.$$

We divide by 8 to save division after quadrature.

With these values of $\frac{c_n}{2}$, $\frac{s_n}{2}$, and the values of the coefficients $b_{\frac{n}{2}}^{(i)}$, we find the values of k_i , K_i , from

$$k_i \cos K_i = b_{\frac{n}{2}}^{(i)} c_{\frac{n}{2}}^{(0)} + \left(b_{\frac{n}{2}}^{(i-1)} + b_{\frac{n}{2}}^{(i+1)} \right) c_{\frac{n}{2}}^{(1)} \\ + \left(b_{\frac{n}{2}}^{(i-1)} - b_{\frac{n}{2}}^{(i+1)} \right) s_{\frac{n}{2}}^{(1)}$$

For $i = 0$, we find k_0 from

$$k_0 = \frac{1}{2} b_{\frac{n}{2}}^{(0)} c_{\frac{n}{2}}^{(0)} + b_{\frac{n}{2}}^{(1)} c_{\frac{n}{2}}^{(1)}.$$

Then in case of $\mu \left(\frac{a}{\Delta}\right)$ from

$$A_{i,\kappa}^{(c)} = \frac{1}{8} m' s k_i \cos [i(Q-g) - K_i]$$

$$A_{i,\kappa}^{(s)} = \frac{1}{8} m' s k_i \sin [i(Q-g) - K_i],$$

where m' is the mass of the disturbing body and $s = 206264''.8$; and from

$$A_{i,\kappa}^{(c)} = \frac{1}{8} m' s \alpha^2 k_i \cos [i(Q-g) - K_i]$$

$$A_{i,\kappa}^{(s)} = \frac{1}{8} m' s \alpha^2 k_i \sin [i(Q-g) - K_i],$$

in case of $\mu\alpha^2 \left(\frac{a}{\Delta}\right)^3$, we find the values of $A_{i,\kappa}^{(c)}$ and $A_{i,\kappa}^{(s)}$ for the 16 different points of the circumference, and the various terms of the series.

Again, since $A_{i,\kappa}^{(c)}$, $A_{i,\kappa}^{(s)}$ are given in the forms

$$A_{i,\kappa}^{(c)} = \Sigma C_{i,\nu}^{(c)} \cos \nu g + \Sigma C_{i,\nu}^{(s)} \sin \nu g$$

$$A_{i,\kappa}^{(s)} = \Sigma S_{i,\nu}^{(c)} \cos \nu g + \Sigma S_{i,\nu}^{(s)} \sin \nu g,$$

we have the following equations to find the values of the coefficients $C_{i,\nu}^{(c)}$, $C_{i,\nu}^{(s)}$, $S_{i,\nu}^{(c)}$, $S_{i,\nu}^{(s)}$:

$$(0.8) = Y_0 + Y_8 \quad \quad \quad \left(\frac{0}{8}\right) = Y_0 - Y_8$$

$$(1.9) = Y_1 + Y_9 \quad \quad \quad \left(\frac{1}{9}\right) = Y_1 - Y_9$$

$$(2.10) = Y_2 + Y_{10} \quad \quad \quad \left(\frac{2}{10}\right) = Y_2 - Y_{10}$$

$$\vdots \quad \quad \quad \vdots$$

$$(7.15) = Y_7 + Y_{15} \quad \quad \quad \left(\frac{7}{15}\right) = Y_7 - Y_{15}$$

$$(0.4) = (0.8) + (4.12)$$

$$(1.5) = (1.9) + (5.13)$$

$$(2.6) = (2.10) + (6.14) \quad \quad \quad (0.2) = (0.4) + (2.6)$$

$$(3.7) = (3.11) + (7.15) \quad \quad \quad (1.3) = (1.5) + (3.7)$$

$$4(c_0 + 2c_8) = (0.2)$$

$$4(c_0 - 2c_8) = (1.3)$$

$$4(c_2 + c_6) = (0.8) - (4.12)$$

$$4(c_2 - c_6) = \{[(1.9) - (5.13)] - [(3.11) - (7.15)]\} \cos 45^\circ$$

$$4(s_2 + s_6) = \{[(1.9) - (5.13)] + [(3.11) - (7.15)]\} \cos 45^\circ$$

$$4(s_2 - s_6) = (2.10) - (6.14)$$

$$8c_4 = (0.4) - (2.6)$$

$$8s_4 = (1.5) - (3.7)$$

$$\begin{aligned}
4(c_1 + c_7) &= \left(\frac{0}{8}\right) + \left[\left(\frac{2}{10}\right) - \left(\frac{6}{14}\right)\right] \cos 45^\circ \\
4(c_1 - c_7) &= \left[\left(\frac{1}{9}\right) - \left(\frac{7}{15}\right)\right] \cos 22^\circ.5 + \left[\left(\frac{3}{11}\right) - \left(\frac{5}{13}\right)\right] \cos 67^\circ.5 \\
4(c_3 + c_5) &= \left(\frac{0}{8}\right) - \left[\left(\frac{2}{10}\right) - \left(\frac{6}{14}\right)\right] \cos 45^\circ \\
4(c_3 - c_5) &= \left[\left(\frac{1}{9}\right) - \left(\frac{7}{15}\right)\right] \sin 22^\circ.5 - \left[\left(\frac{3}{11}\right) - \left(\frac{5}{13}\right)\right] \sin 67^\circ.5 \\
4(s_1 + s_7) &= \left[\left(\frac{1}{9}\right) + \left(\frac{7}{15}\right)\right] \sin 22^\circ.5 + \left[\left(\frac{3}{11}\right) + \left(\frac{5}{13}\right)\right] \sin 67^\circ.5 \\
4(s_1 - s_7) &= \left[\left(\frac{2}{10}\right) + \left(\frac{6}{14}\right)\right] \cos 45^\circ + \left(\frac{4}{12}\right) \\
4(s_3 + s_5) &= \left[\left(\frac{1}{9}\right) + \left(\frac{7}{15}\right)\right] \cos 22^\circ.5 - \left[\left(\frac{3}{11}\right) + \left(\frac{5}{13}\right)\right] \cos 67^\circ.5 \\
4(s_3 - s_5) &= \left[\left(\frac{2}{10}\right) + \left(\frac{6}{14}\right)\right] \cos 45^\circ - \left(\frac{4}{12}\right)
\end{aligned}$$

The values of c_ν , s_ν must satisfy the equation

$$\begin{aligned}
A_{i,\kappa}^{(c)} \text{ or } A_{i,\kappa}^{(s)} &= \frac{1}{2} c_0 + c_1 \cos g + c_2 \cos 2g + \text{etc.} \\
&+ s_1 \sin g + s_2 \sin 2g + \text{etc.}
\end{aligned}$$

i answering to i in $b_n^{(i)}$, and κ being any one of the numbers, from 0 to 15 inclusive, into which the circumference is divided. We use c_ν , s_ν as abbreviated forms of $C_{i,\nu}^{(c)}$, $C_{i,\nu}^{(s)}$, etc. Having found the values of c_ν , s_ν from the 16 different values of $A_0^{(c)}$, $A_1^{(c)}$, $A_1^{(s)}$, $A_2^{(c)}$, $A_2^{(s)}$, . . . $A_9^{(c)}$, $A_9^{(s)}$, both for $\mu \left(\frac{a}{d}\right)$ and $\mu \alpha^2 \left(\frac{a}{d}\right)$, we have the values of these functions given by the equation

$$\left(\frac{a}{d}\right)^n = \frac{1}{2} \Sigma \Sigma (C_{i,r}^{(c)} \mp S_{i,r}^{(s)}) \cos [(i \mp r)g - iE'] \mp \frac{1}{2} \Sigma \Sigma (C_{i,r}^{(s)} \pm S_{i,r}^{(c)}) \sin [(i \mp r)g - iE]$$

The values of the most important quantities from the eccentric anomaly E to c_ν , s_ν , needed in the expansion of $\mu \left(\frac{a}{d}\right)$ and $\mu \alpha^2 \left(\frac{a}{d}\right)^3$, are given in the following tables, first for $\mu \left(\frac{a}{d}\right)$, and then for $\mu \alpha^2 \left(\frac{a}{d}\right)^3$, when not common to both.

Values of Quantities in the Development of $\mu\left(\frac{a}{\Delta}\right)$ and $\mu a^2\left(\frac{a}{\Delta}\right)^3$.

g	E	$E + W$	$E + W_1$	$F - P$	F
	° ' "	° ' "	° ' "	° ' "	° ' "
(0)	0 0 0.0	266 4 39.5	266 15 38.0	266 21 17.2	359 24 44.2
(1)	24 24 4.2	290 28 43.7	290 39 42.2	290 8 7.8	23 11 34.8
(2)	48 26 37.2	314 31 16.7	314 42 15.2	313 40 58.4	46 44 25.4
(3)	71 52 24.9	337 57 4.4	338 8 2.9	336 53 39.3	69 57 6.3
(4)	94 35 14.0	0 39 53.5	0 50 52.0	359 41 1.3	92 44 28.3
(5)	116 36 51.7	22 41 31.2	22 52 29.7	21 59 7.8	115 2 34.8
(6)	138 4 29.4	44 9 8.9	44 20 7.4	43 47 3.8	136 50 30.8
(7)	159 8 19.6	65 12 59.1	65 23 57.6	65 8 48.4	158 12 15.4
(8)	180 0 0.0	86 4 39.5	86 15 38.0	86 13 41.4	179 17 8.4
(9)	200 51 40.4	106 56 19.9	107 7 18.4	107 15 14.8	200 18 41.8
(10)	221 55 30.6	128 0 10.1	128 11 8.6	128 28 47.5	221 32 14.5
(11)	243 23 8.3	149 27 47.8	149 38 46.3	150 8 27.6	243 11 54.6
(12)	265 24 46.0	171 29 25.5	171 40 24.0	172 23 51.4	265 27 18.4
(13)	288 7 35.1	194 12 14.6	194 23 13.1	195 17 19.4	288 20 46.4
(14)	311 33 22.8	217 38 2.3	217 49 0.8	218 43 0.9	311 46 27.9
(15)	335 35 55.8	241 40 35.3	241 51 33.8	242 28 57.5	335 32 24.5
Σ					1613 47 17.9
Σ'					1433 47 18.6

g	$\text{Log. } f.$	y	x	Q	$\text{Log. } q.$	$\text{Log. } C.$
			"	° ' "		
(0)	0.612427	— .001251	— 12.2	359 24 32.0	0.611176	0.706582
(1)	0.612078	— .000860	+ 431.5	23 18 46.3	0.611218	0.706349
(2)	0.609315	— .000081	+ 598.0	46 54 23.4	0.609234	0.705534
(3)	0.605242	+ .000981	+ 390.0	70 3 36.3	0.606233	0.704403
(4)	0.601312	+ .001292	— 58.6	92 43 29.7	0.602604	0.703241
(5)	0.598569	+ .000846	— 476.9	114 54 37.9	0.599415	0.702241
(6)	0.597310	+ .000091	— 626.7	136 40 4.1	0.597401	0.701493
(7)	0.597194	— .000956	— 435.1	158 5 0.3	0.596238	0.701011
(8)	0.597621	— .001322	— 15.7	179 16 52.7	0.596299	0.700788
(9)	0.598109	— .000997	+ 408.7	200 25 30.5	0.597112	0.700494
(10)	0.598532	— .000152	+ 618.1	221 42 32.6	0.598380	0.700021
(11)	0.599177	+ .000777	+ 496.6	243 20 11.2	0.599954	0.699872
(12)	0.600584	+ .001278	+ 96.7	265 28 55.1	0.601862	0.700504
(13)	0.603163	+ .001032	— 363.1	288 14 43.3	0.604195	0.702020
(14)	0.606734	+ .000148	— 600.1	311 36 27.8	0.606882	0.704038
(15)	0.610302	— .000825	— 452.4	335 24 52.1	0.609477	0.705810
Σ	4.823835	+ 3	— 0.5	1613 47 17.4	4.823838	5.622201
Σ'	4.823834	— 2	— 0.7	1433 47 17.9	4.823842	5.622200

Values of Quantities in the Development of $\mu\left(\frac{a}{d}\right)$ and $\mu a^2\left(\frac{a}{d}\right)^3$.

g	χ	χ_1	Log. b .	Log. a .	a .	Log. N .
	" "	" "				
(0)	53 23 45.3	7 57.83	7.063818	9.701484	0.502902	9.695669
(1)	53 26 41.3	7 57.78	7.063792	9.701945	0.503437	9.695880
(2)	53 14 15.6	7 59.97	7.065778	9.699988	0.501173	9.695892
(3)	52 54 33.7	8 3.30	7.068781	9.696876	0.497594	9.695837
(4)	52 28 55.6	8 7.35	7.072405	9.692804	0.492951	9.695616
(5)	52 6 31.2	8 10.95	7.075601	9.689226	0.488907	9.695421
(6)	51 53 41.2	8 13.23	7.077613	9.687169	0.486597	9.695400
(7)	51 46 50.0	8 14.55	7.078774	9.686068	0.485364	9.695430
(8)	51 49 41.2	8 14.49	7.078721	9.686526	0.485877	9.695629
(9)	52 0 52.3	8 13.57	7.077913	9.688321	0.487889	9.696120
(10)	52 18 36.9	8 12.12	7.076635	9.691160	0.491089	9.696905
(11)	52 36 21.2	8 10.34	7.075061	9.693986	0.494294	9.697532
(12)	52 49 37.5	8 8.19	7.073153	9.696093	0.496699	9.697631
(13)	52 58 10.6	8 5.58	7.070825	9.697448	0.498251	9.697141
(14)	53 5 12.5	8 2.58	7.068133	9.698559	0.499527	9.696354
(15)	53 13 54.4	7 59.70	7.065534	9.699932	0.501109	9.695743
Σ				77.553783	3.956815	77.569096
Σ''				77.553803	3.956845	77.569088

g	Log. $\frac{1}{8} c_{\frac{1}{2}}^{(0)}$	Log. $\frac{1}{8} c_{\frac{1}{2}}^{(1)}$	Log. $\frac{1}{8} s_{\frac{1}{2}}^{(1)}$	Log. $b_{\frac{1}{2}}^{(0)}$	Log. $b_{\frac{1}{2}}^{(1)}$	Log. $b_{\frac{1}{2}}^{(2)}$
(0)	8.792579	6.16064	4.47527 n	0.332110	9.748094	9.329969
(1)	8.792790	5.98934	6.02920	0.332186	9.748669	9.331018
(2)	8.792802	4.98551 n	6.16173	0.331867	9.746235	9.326571
(3)	8.792731	6.05070 n	5.97267	0.331369	9.742375	9.319511
(4)	8.792526	6.16734 n	5.14693 n	0.330730	9.737346	9.310298
(5)	8.792331	5.98219 n	6.05562 n	0.330182	9.732946	9.302224
(6)	8.792310	4.93934	6.17378 n	0.329872	9.730425	9.297590
(7)	8.792340	6.03383	6.01614 n	0.329707	9.729076	9.295111
(8)	8.792539	6.17549	4.57507 n	0.329776	9.729636	9.296143
(9)	8.793030	6.05359	5.99045	0.320045	9.731836	9.300183
(10)	8.793815	5.23282	6.17067	0.330477	9.735322	9.306586
(11)	8.794442	5.94812 n	6.07618	0.330914	9.738805	9.312970
(12)	8.794541	6.16466 n	5.36611	0.331246	9.741407	9.317738
(13)	8.794051	6.07296 n	5.94202 n	0.331460	9.743073	9.320808
(14)	8.793264	5.23742 n	6.16200 n	0.331637	9.744461	9.323327
(15)	8.792653	5.97789	6.04134 n	0.331858	9.746165	9.326443
Σ				2.647715	77.912926	74.508222
Σ''				2.647721	77.912945	74.508268

Values of Quantities in the Development of $\mu\left(\frac{a}{A}\right)$ and $\mu\alpha^2\left(\frac{a}{A}\right)^3$.

g	Log. $b_{\frac{1}{2}}^{(3)}$	Log. $b_{\frac{1}{2}}^{(4)}$	Log. $b_{\frac{1}{2}}^{(5)}$	Log. $b_{\frac{1}{2}}^{(6)}$	Log. $b_{\frac{1}{2}}^{(7)}$	Log. $b_{\frac{1}{2}}^{(8)}$	Log. $b_{\frac{1}{2}}^{(9)}$
(0)	8.954999	8.60017	8.2570	7.9215	7.5915	7.2654	6.9426
(1)	8.956515	8.60214	8.2594	7.9244	7.5947	7.2691	6.9468
(2)	8.950082	8.59373	8.2490	7.9120	7.5804	7.2528	6.9286
(3)	8.939865	8.58036	8.2326	7.8926	7.5578	7.2271	6.8997
(4)	8.926521	8.56292	8.2110	7.8668	7.5280	7.1932	6.8617
(5)	8.914818	8.54760	8.1921	7.8444	7.5020	7.1636	6.8285
(6)	8.908100	8.53882	8.1812	7.8314	7.4870	7.1466	6.8094
(7)	8.904506	8.53411	8.1754	7.8244	7.4789	7.1373	6.7991
(8)	8.906000	8.53606	8.1778	7.8273	7.4822	7.1411	6.8033
(9)	8.911861	8.54373	8.1872	7.8386	7.4953	7.1561	6.8201
(10)	8.921142	8.55588	8.2024	7.8565	7.5160	7.1796	6.8464
(11)	8.930392	8.56797	8.2172	7.8742	7.5367	7.2031	6.8728
(12)	8.937298	8.57701	8.2285	7.8875	7.5520	7.2205	6.8923
(13)	8.941742	8.58283	8.2355	7.8960	7.5618	7.2317	6.9048
(14)	8.945388	8.58760	8.2415	7.9030	7.5700	7.2410	6.9152
(15)	8.949898	8.59349	8.2488	7.9117	7.5800	7.2524	6.9280
Σ	71.449530	68.55219	65.7484	63.0060	60.3071	57.6402	54.9995
Σ'	71.449597	68.55223	65.7482	63.0063	60.3072	57.6404	54.9998

g	Log. $\frac{1}{8} N^3$	Log. $\frac{1}{8} c_{\frac{3}{2}}^{(1)}$	Log. $\frac{1}{8} s_{\frac{3}{2}}^{(1)}$	Log. $\frac{1}{2} b_{\frac{3}{2}}^{(0)}$	Log. $b_{\frac{3}{2}}^{(1)}$	Log. $b_{\frac{3}{2}}^{(2)}$	Log. $b_{\frac{3}{2}}^{(3)}$
(0)	8.183917	5.42374	3.73837 n	0.280319	0.417421	0.200612	9.961097
(1)	8.184550	5.25307	5.29293	0.281000	0.418474	0.202090	9.963016
(2)	8.184586	4.24928 n	5.42550	0.278120	0.414013	0.195824	9.954877
(3)	8.184421	5.31430 n	5.23627	0.273612	0.406981	0.185917	9.941987
(4)	8.183758	5.43028 n	4.40987 n	0.267827	0.397890	0.173060	9.925223
(5)	8.183173	5.24454 n	5.31797 n	0.262860	0.390004	0.161858	9.910585
(6)	8.183110	4.20163	5.43607 n	0.260054	0.385513	0.155458	9.902210
(7)	8.183200	5.29621	5.27852 n	0.258559	0.383116	0.152039	9.897732
(8)	8.183797	5.43847	3.83805 n	0.259184	0.384116	0.153464	9.899598
(9)	8.185270	5.31804	5.25490	0.261621	0.388024	0.159038	9.906900
(10)	8.187625	4.49962	5.43747	0.265530	0.394254	0.167901	9.918485
(11)	8.189506	5.21681 n	5.34487	0.269488	0.400515	0.176758	9.930076
(12)	8.189803	5.43364 n	4.63509	0.272484	0.405223	0.183435	9.938754
(13)	8.188333	5.34047 n	5.20953 n	0.274429	0.408267	0.187732	9.944350
(14)	8.185972	4.50257 n	5.42714 n	0.276036	0.410773	0.191265	9.948948
(15)	8.184139	5.24121	5.30466 n	0.278037	0.413885	0.195644	9.954643
Σ	65.482568			2.159554	3.209203	1.421019	79.449192
Σ'	65.482592			2.159606	3.209266	1.421076	79.449289

Values of Quantities in the Development of $\mu\left(\frac{a}{d}\right)$ and $\mu\alpha^2\left(\frac{a}{d}\right)^3$.

g	Log. $b_{\frac{3}{2}}^{(4)}$	Log. $b_{\frac{3}{2}}^{(5)}$	Log. $b_{\frac{3}{2}}^{(6)}$	Log. $b_{\frac{3}{2}}^{(7)}$	Log. $b_{\frac{3}{2}}^{(8)}$	Log. $b_{\frac{3}{2}}^{(9)}$
(0)	9.70884	9.4484	9.1822	8.9118	8.6383	8.3621
(1)	9.71121	9.4512	9.1854	8.9155	8.6423	8.3665
(2)	9.70116	9.4393	9.1716	8.8998	8.6247	8.3471
(3)	9.68524	9.4203	9.1496	8.8747	8.5965	8.3158
(4)	9.66450	9.3955	9.1207	8.8418	8.5595	8.2747
(5)	9.64638	9.3739	9.0956	8.8131	8.5273	8.2389
(6)	9.63600	9.3614	9.0813	8.7968	8.5089	8.2184
(7)	9.63043	9.3549	9.0735	8.7880	8.4991	8.2077
(8)	9.63276	9.3576	9.0766	8.7914	8.5030	8.2119
(9)	9.64181	9.3684	9.0893	8.8058	8.5191	8.2298
(10)	9.65617	9.3856	9.1093	8.8287	8.5449	8.2585
(11)	9.67052	9.4028	9.1292	8.8515	8.5705	8.2868
(12)	9.68125	9.4156	9.1440	8.8684	8.5893	8.3078
(13)	9.68816	9.4237	9.1537	8.8791	8.6015	8.3213
(14)	9.69382	9.4305	9.1614	8.8882	8.6118	8.3329
(15)	9.70087	9.4389	9.1711	8.8992	8.6240	8.3464
Σ	77.37450	75.2339	73.0471	70.8269	68.5804	66.3134
Σ'	77.37462	75.2341	73.0474	70.8269	68.5803	66.3132

g	Log. k_0	Log. k_1	Log. k_2	Log. k_3	Log. k_4	Log. k_5	Log. k_6	Log. k_7
(0)	8.824187	8.54492	8.12562	7.750420	7.39550	7.0523	6.7168	6.4105
(1)	8.824302	8.54433	8.12588	7.751220	7.39678	7.0540	6.7190	6.4054
(2)	8.823605	8.53875	8.11916	7.742693	7.38634	7.0416	6.7046	6.3714
(3)	8.822665	8.53172	8.10982	7.730361	7.37091	7.0232	6.6832	6.3298
(4)	8.821701	8.52543	8.09963	7.716100	7.35261	7.0007	6.6565	6.2932
(5)	8.821143	8.52236	8.09246	7.705215	7.33807	6.9826	6.6349	6.2764
(6)	8.821183	8.52300	8.09009	7.700585	7.33130	6.9737	6.6239	6.2809
(7)	8.821397	8.52470	8.08981	7.699023	7.32855	6.9698	6.6187	6.2913
(8)	8.821810	8.52671	8.09164	7.701551	7.33151	6.9732	6.6226	6.3027
(9)	8.822444	8.52829	8.09567	7.707159	7.33895	6.9824	6.6337	6.3093
(10)	8.823323	8.52965	8.10077	7.715298	7.35002	6.9965	6.6506	6.3129
(11)	8.824009	8.53059	8.10550	7.723069	7.36070	7.0100	6.6669	6.3147
(12)	8.824233	8.53159	8.10915	7.728940	7.36874	7.0202	6.6793	6.3196
(13)	8.824055	8.53359	8.11233	7.733450	7.37462	7.0274	6.6879	6.3342
(14)	8.823809	8.53721	8.11622	7.738311	7.38053	7.0345	6.6960	6.3608
(15)	8.823826	8.54164	8.12113	7.744423	7.38795	7.0433	6.7062	6.3901
Σ	70.583851	68.25726	64.85258	61.793910	58.89655	56.0927	53.3503	50.6520
Σ'	70.583841	68.25722	64.85260	61.793920	58.89653	56.0926	53.3505	50.6512

Values of Quantities in the Development of $\mu\left(\frac{a}{d}\right)$ and $\mu\alpha^2\left(\frac{a}{d}\right)^3$.

g	Log. k_8 Log. k_9		K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_9
(0)	6.0606	5.7378	— 0.6	— 0.4	— 0.3	— 0.3	— 0.3	— 0.3	— 0.3	— 0.3
(1)	6.0636	5.7413	+20.3	+12.9	+11.4	+11.1	+10.6	+10.1	+ 9.5	+ 8.3
(2)	6.0454	5.7212	+27.9	+17.8	+15.6	+15.2	+14.6	+14.0	+13.5	+12.5
(3)	6.0178	5.6904	+18.4	+11.7	+10.2	+10.0	+ 9.7	+ 9.4	+ 9.2	+ 8.8
(4)	5.9830	5.6515	— 2.8	— 1.8	— 1.6	— 1.5	— 1.5	— 1.5	— 1.5	— 1.5
(5)	5.9541	5.6191	—22.7	—14.5	—12.7	—12.0	—11.8	—11.6	—11.4	—11.0
(6)	5.9391	5.6019	—29.8	—19.0	—16.7	—15.7	—15.3	—14.9	—14.5	—13.7
(7)	5.9316	5.5934	—20.7	—13.2	—11.6	—10.9	—10.5	—10.1	— 9.7	— 8.9
(8)	5.9364	5.5985	— 0.7	— 0.5	— 0.4	— 0.4	— 0.4	— 0.3	— 0.3	— 0.3
(9)	5.9512	5.6151	+19.3	+12.3	+10.9	+10.2	+ 9.8	+ 9.4	+ 9.0	+ 8.2
(10)	5.9737	5.6405	+29.1	+18.6	+16.4	+15.3	+14.9	+14.5	+14.1	+13.3
(11)	5.9959	5.6656	+23.4	+14.9	+13.1	+12.3	+12.1	+11.9	+11.7	+11.3
(12)	6.0124	5.6842	+ 4.5	+ 2.8	+ 2.5	+ 2.4	+ 2.4	+ 2.3	+ 2.3	+ 2.2
(13)	6.0251	5.6968	—17.0	—10.8	— 9.5	— 8.9	— 8.8	— 8.7	— 8.6	— 8.4
(14)	6.0341	5.7083	—28.1	—17.8	—15.7	—14.7	—14.3	—13.9	—13.6	—13.0
(15)	6.0468	5.7224	—21.0	—13.4	—11.8	—11.0	—10.6	—10.2	— 9.8	— 9.0
Σ		45.3439	— .5	— .3	— .2	+ .3			— .3	
Σ'		45.3441	0	— .1	0	+ .8			— .1	

g	Log. k_0	Log. k_1	Log. k_2	Log. k_3	Log. k_4	Log. k_5	Log. k_6	Log. k_7
(0)	8.465272	8.60289	8.38621	8.14674	7.89481	7.6341	7.3679	7.0975
(1)	8.466247	8.60407	8.38777	8.14874	7.89694	7.6369	7.3712	7.1013
(2)	8.462637	8.59849	8.38030	8.13935	7.88563	7.6238	7.3561	7.0843
(3)	8.457236	8.59018	8.36903	8.12505	7.86829	7.6033	7.3326	7.0577
(4)	8.450550	8.58006	8.35509	8.10719	7.84645	7.5774	7.3026	7.0237
(5)	8.445362	8.57214	8.34391	8.09259	7.82837	7.5559	7.2776	6.9950
(6)	8.443224	8.56872	8.33868	8.08543	7.81922	7.5446	7.2645	6.9800
(7)	8.442508	8.56750	8.33651	8.08224	7.81495	7.5395	7.2581	6.9726
(8)	8.444020	8.56954	8.33902	8.08521	7.81840	7.5433	7.2623	6.9771
(9)	8.444679	8.57452	8.34564	8.09354	7.82847	7.5551	7.2760	6.9925
(10)	8.453274	8.58206	8.35573	8.10632	7.84401	7.5734	7.2971	7.0165
(11)	8.458368	8.58906	8.36522	8.11851	7.85895	7.5912	7.3176	7.0400
(12)	8.461465	8.59345	8.37153	8.12680	7.86927	7.6036	7.3320	7.0564
(13)	8.461922	8.59532	8.37468	8.13126	7.87506	7.6105	7.3405	7.0660
(14)	8.461886	8.59651	8.37704	8.13471	7.87957	7.6163	7.3472	7.0739
(15)	8.462852	8.59905	8.38088	8.13992	7.88616	7.6242	7.3564	7.0845
Σ		68.69172	66.90360	64.93175	62.85706	60.7165	58.5297	56.3095
Σ'		68.69184	66.90364	64.93185	62.85719	60.7166	58.5300	56.3096

Values of Quantities in the Development of $\mu\left(\frac{a}{\Delta}\right)$ and $\mu\alpha^2\left(\frac{a}{\Delta}\right)^8$.

g	Log. k_8	Log. k_9	K_1	K_3	K_7	$(Q-g)-K_1$	$2(Q-g)-K_2$	$3(Q-g)-K_3$
			/	/	/	° / "		
(0)	6.8240	6.5478	—0.1	—0.1	—0.1	359 25.1	358 49.5	358 13 55.0
(1)	6.8280	6.5522	+4.4	+4.4	+4.4	0 28.5	1 24.6	2 14 57.0
(2)	6.8092	6.5317	+6.0	+6.0	+6.0	1 26.5	3 31.0	5 27 34.4
(3)	6.7795	6.4988	+3.9	+3.9	+3.9	2 15.2	4 55.5	7 30 33.9
(4)	6.7414	6.4566	—0.6	—0.6	—0.6	2 46.3	5 28.8	8 12 2.4
(5)	6.7093	6.4209	—4.7	—4.7	—4.7	2 47.3	5 3.8	7 26 37.6
(6)	6.6921	6.4016	—6.2	—6.2	—6.2	2 9.9	3 39.1	5 16 57.0
(7)	6.6837	6.3923	—4.3	—4.3	—4.3	0 55.7	1 23.2	1 56 39.0
(8)	6.6887	6.3976	—0.2	—0.2	—0.2	359 17.6	358 34.3	357 51 3.3
(9)	6.7058	6.4165	+4.0	+4.0	+4.0	357 36.2	355 38.7	353 35 39.5
(10)	6.7327	6.4463	+6.1	+6.1	+6.1	356 13.4	353 6.5	349 51 14.9
(11)	6.7589	6.4752	+5.0	+5.0	+5.0	355 26.8	351 25.5	347 17 29.4
(12)	6.7773	6.4958	+1.0	+1.0	+1.0	355 24.4	350 55.0	346 24 12.8
(13)	6.7883	6.5081	—3.5	—3.5	—3.5	356 1.7	351 40.2	347 23 40.2
(14)	6.7976	6.5187	—6.0	—6.0	—6.0	357 4.6	353 30.7	350 5 3.8
(15)	6.8093	6.5317	—4.5	—4.5	—4.5	358 15.9	356 3.1	353 56 22.5
Σ	54.0630	51.7961	.0	.0	.0	1793 47.8		1781 22 3.6
Σ'	54.0628	51.7957	+ .3	+ .3	+ .3	1433 47.3		1421 21 59.1

g	$4(Q-g)-K_4$	$5(Q-g)-K_5$	$6(Q-g)-K_6$	$7(Q-g)-K_7$	$8(Q-g)-K_8$	$9(Q-g)-K_9$
	° /		° /	° /	° /	° /
(0)	357 38.5	357 3.0	356 27.5	355 52.1	355 16.7	354 41.2
(1)	3 3.9	3 53.2	4 42.5	5 31.8	6 21.1	7 10.5
(2)	7 22.4	9 17.4	11 12.4	13 7.3	15 2.2	16 57.1
(3)	10 4.4	12 38.3	15 12.2	17 46.0	20 19.8	22 53.6
(4)	10 55.5	13 39.0	16 22.5	19 6.0	21 49.5	24 33.0
(5)	9 50.6	12 15.0	14 39.4	17 3.9	19 28.4	21 52.8
(6)	6 55.9	8 35.6	10 15.3	11 54.9	13 34.5	15 14.2
(7)	2 30.9	3 5.5	3 40.1	4 14.7	4 49.3	5 23.9
(8)	357 8.0	356 24.9	355 41.7	354 58.6	354 15.5	353 32.4
(9)	351 31.8	349 27.7	347 23.6	345 19.5	343 15.4	341 11.3
(10)	346 34.9	343 17.8	340 0.7	336 43.7	333 26.7	330 9.6
(11)	343 8.5	338 58.9	334 49.3	330 39.7	326 30.1	322 20.5
(12)	341 53.2	337 22.1	332 51.1	328 20.0	323 48.9	319 17.9
(13)	343 7.7	338 52.3	334 36.9	330 21.5	326 6.1	321 50.7
(14)	346 40.5	342 16.6	339 52.7	336 28.8	333 4.9	329 41.1
(15)	351 50.4	349 44.9	347 39.4	345 33.8	343 28.2	341 22.7
Σ						1744 6.5
Σ'						1384 6.0

In the expansion of $\mu \left(\frac{a}{A} \right)$.

g	$A_0^{(c)}$	$A_1^{(c)}$	$A_1^{(s)}$	$A_2^{(c)}$	$A_2^{(s)}$	$A_3^{(c)}$	$A_3^{(s)}$	$A_4^{(c)}$	$A_4^{(s)}$
	"	"	"	"	"	"	"	"	"
(0)	13.13109	6.9027	— .0701	+2.6281	— .0539	+1.10745	— .03418	+ .4889	— .0201
(1)	13.13458	6.8933	+ .0571	2.6294	+ .0647	1.10917	+ .04356	.4901	+ .0262
(2)	13.11352	6.8033	+ .1712	2.5849	+ .1588	1.08348	+ .10356	.4751	+ .0615
(3)	13.08513	6.6912	+ .2633	2.5254	+ .2176	1.04890	+ .13827	.4553	+ .0809
(4)	13.05615	6.5922	+ .3192	2.4646	+ .2364	1.01333	+ .14604	.4353	+ .0840
(5)	13.03939	6.5457	+ .3187	2.4259	+ .2150	0.99004	+ .12935	.4224	+ .0733
(6)	13.04058	6.5584	+ .2479	2.4172	+ .1543	0.98367	+ .09095	.4190	+ .0509
(7)	13.04700	6.5880	+ .1067	2.4198	+ .0585	0.98375	+ .03339	.4190	+ .0184
(8)	13.05942	6.6190	— .0816	2.4317	— .0606	0.98937	— .03712	.4218	— .0211
(9)	13.07850	6.6377	— .2779	2.4464	— .1863	0.99667	— .11189	.4249	— .0633
(10)	13.10500	6.6498	— .4389	2.4645	— .2979	1.00593	— .18002	.4287	— .1023
(11)	13.12573	6.6578	— .5301	2.4816	— .3742	1.01487	— .22886	.4322	— .1310
(12)	13.13248	6.6727	— .5359	2.4991	— .3995	1.02497	— .24789	.4373	— .1431
(13)	13.12612	6.7090	— .4658	2.5224	— .3693	1.03984	— .23254	.4463	— .1354
(14)	13.11967	6.7727	— .3458	2.5559	— .2907	1.06142	— .18555	.4600	— .1090
(15)	13.12018	6.8478	— .2074	2.5954	— .1791	1.08668	— .11537	.4760	— .0683
Σ	104.75791	53.5708	— .7340	+20.0460	— .5531	8.26962	— .34421	+3.5661	— .1992
Σ'	104.75663	53.5705	— .7354	+20.0463	— .5531	8.26992	— .34409	+3.5662	— .1992

g	$A_5^{(c)}$	$A_5^{(s)}$	$A_6^{(c)}$	$A_6^{(s)}$	$A_7^{(c)}$	$A_7^{(s)}$	$A_8^{(c)}$	$A_8^{(s)}$	$A_9^{(c)}$	$A_9^{(s)}$
	"	"	"	"	"	"	"	"	"	"
(0)	+ .2217	— .0114	+ .1023	— .0063	+ .0505	— .0036	+ .0226	— .0019	+ .0107	— .0010
(1)	.2223	+ .0151	.1027	+ .0085	.0498	+ .0048	.0226	+ .0025	.0108	+ .0014
(2)	.2138	+ .0350	.0978	+ .0194	.0451	+ .0105	.0211	+ .0057	.0099	+ .0030
(3)	.2028	+ .0454	.0916	+ .0249	.0401	+ .0128	.0192	+ .0071	.0089	+ .0038
(4)	.1916	+ .0465	.0856	+ .0252	.0365	+ .0126	.0176	+ .0070	.0080	+ .0037
(5)	.1848	+ .0401	.0821	+ .0215	.0356	+ .0109	.0167	+ .0059	.0076	+ .0030
(6)	.1832	+ .0277	.0815	+ .0147	.0368	+ .0078	.0166	+ .0040	.0076	+ .0021
(7)	.1833	+ .0099	.0816	+ .0052	.0384	+ .0028	.0168	+ .0014	.0077	+ .0007
(8)	.1847	— .0116	.0823	— .0062	.0394	— .0035	.0169	— .0017	.0078	— .0009
(9)	.1860	— .0346	.0826	— .0185	.0388	— .0102	.0168	— .0051	.0077	— .0026
(10)	.1870	— .0561	.0827	— .0301	.0372	— .0160	.0166	— .0083	.0075	— .0043
(11)	.1880	— .0722	.0827	— .0389	.0354	— .0199	.0163	— .0108	.0072	— .0056
(12)	.1904	— .0793	.0837	— .0429	.0350	— .0216	.0163	— .0120	.0072	— .0062
(13)	.1956	— .0756	.0867	— .0411	.0369	— .0210	.0173	— .0116	.0077	— .0060
(14)	.2041	— .0613	.0918	— .0336	.0414	— .0180	.0190	— .0096	.0087	— .0051
(15)	.2140	— .0387	.0978	— .0214	.0468	— .0120	.0210	— .0062	.0098	— .0033
Σ	+1.5765	— .1105	+ .7077	— .0598	+ .3219	— .0318	+ .1467	— .0168	+ .0674	— .0087
Σ'	+1.5768	— .1106	+ .7078	— .0598	+ .3218	— .0318	+ .1467	— .0168	+ .0674	— .0086

In the expansion of $\mu \alpha^2 \left(\frac{a}{d}\right)^3$.

g	$A_0^{(c)}$	$A_1^{(c)}$	$A_1^{(s)}$	$A_2^{(c)}$	$A_2^{(s)}$	$A_3^{(c)}$	$A_3^{(s)}$	$A_4^{(c)}$	$A_4^{(s)}$
	"	"	"	"	"	"	"	"	"
(0)	23.3520	+32.0569	-0.3301	+19.4613	-0.4009	+11.2092	-0.3464	+6.269	-0.258
(1)	23.4045	32.1423	+0.4199	19.5273	+0.5272	11.2569	+0.4603	6.300	+0.347
(2)	23.2107	31.7192	+1.0033	19.1618	+1.2486	10.9731	+1.0737	6.096	+0.802
(3)	22.9239	31.1043	+1.3503	18.6375	+1.6470	10.5748	+1.4097	5.813	+1.041
(4)	22.5737	30.3821	+1.4503	18.0367	+1.7240	10.1342	+1.4580	5.516	+1.063
(5)	22.3056	29.8387	+1.2952	17.5937	+1.5122	9.8190	+1.2644	5.310	+0.912
(6)	22.1960	29.6180	+0.9110	17.4156	+1.0505	9.6988	+0.8734	5.239	+0.626
(7)	22.1595	29.5473	+0.3342	17.3564	+0.3782	9.6618	+0.3118	5.219	+0.222
(8)	22.2368	29.6867	-0.3713	17.4552	-0.4367	9.7264	-0.3654	5.259	-0.204
(9)	22.4249	30.0100	-1.1187	17.6808	-1.3068	9.8617	-1.0915	5.331	-0.786
(10)	22.7157	30.5036	-1.8033	18.0224	-2.1155	10.0630	-1.7762	5.436	-1.285
(11)	22.9837	30.9679	-2.3042	18.3471	-2.7150	10.2558	-2.2962	5.536	-1.667
(12)	23.1482	31.2707	-2.4810	18.5835	-2.9616	10.4121	-2.5144	5.627	-1.839
(13)	23.1725	31.4193	-2.3026	18.7500	-2.7837	10.5580	-2.3763	5.739	-1.748
(14)	23.1706	31.5386	-1.8212	18.9291	-2.2155	10.7412	-1.9027	5.895	-1.409
(15)	23.2222	31.7564	-1.1097	19.1791	-1.3716	10.9764	-1.1843	6.091	-.882
Σ	182.6038	246.7758	-3.4423	147.0656	-4.1071	82.9580	-3.5000	+45.337	-2.564
Σ'	182.5968	246.7862	-3.4356	147.0719	-4.1125	82.9644	-3.4985	+45.339	-2.563

g	$A_5^{(c)}$	$A_5^{(s)}$	$A_6^{(c)}$	$A_6^{(s)}$	$A_7^{(c)}$	$A_7^{(s)}$	$A_8^{(c)}$	$A_8^{(s)}$	$A_9^{(c)}$	$A_9^{(s)}$
	"	"	"	"	"	"	"	"	"	"
(0)	+3.440	-0.177	+1.863	-.115	+1.000	-.072	+5.32	-.044	+2.82	-.027
(1)	3.458	+0.240	1.874	+1.157	1.005	+0.098	.535	+0.060	.283	+0.036
(2)	3.318	+0.550	1.781	+3.356	.944	+2.221	.497	+1.134	.260	+0.076
(3)	3.130	+0.706	1.660	+4.53	.868	+2.79	.450	+1.167	.231	+0.098
(4)	2.937	+0.713	1.540	+4.53	.797	+2.76	.409	+1.164	.208	+0.095
(5)	2.812	+0.606	1.467	+3.81	.756	+2.32	.377	+1.133	.196	+0.078
(6)	2.772	+0.413	1.448	+2.60	.748	+1.57	.383	+0.92	.195	+0.053
(7)	2.766	+0.146	1.446	+0.91	.750	+0.055	.386	+0.032	.197	+0.019
(8)	2.789	-0.175	1.459	-.110	.757	-0.053	.389	-0.039	.199	-0.023
(9)	2.824	-0.522	1.474	-3.29	.760	-1.99	.389	-1.17	.197	-0.067
(10)	2.870	-0.855	1.491	-5.40	.759	-3.26	.385	-1.192	.193	-1.11
(11)	2.915	-1.115	1.505	-7.05	.757	-4.25	.379	-2.51	.187	-1.144
(12)	2.963	-1.235	1.528	-7.83	.767	-4.73	.382	-2.80	.188	-1.162
(13)	3.042	-1.179	1.582	-7.53	.803	-4.57	.404	-2.72	.201	-1.158
(14)	3.164	-0.957	1.670	-6.15	.867	-3.78	.446	-2.27	.227	-1.133
(15)	3.312	-0.604	1.775	-3.91	.942	-2.43	.495	-1.47	.259	-0.087
Σ	24.253	-1.723	12.780	-1.094	+6.639	-.648	+3.423	-.392	+1.752	-.232
Σ'	24.259	-1.722	12.783	-1.095	6.641	-.660	+3.415	-.395	1.751	-.225

The Quantities $\frac{1}{2}C_{i,\nu}^{(c)}$, $\frac{1}{2}C_{i,\nu}^{(s)}$, $\frac{1}{2}S_{i,\nu}^{(c)}$, $\frac{1}{2}S_{i,\nu}^{(s)}$, arranged for Quadrature in the Expansion of

$$\mu \left(\frac{a}{\Delta} \right).$$

	$i = 0$	$i = 1$	$i = 2$	$i = 3$	$i = 4$	$i = 5$	$i = 6$
$\nu=0$	$C_{i,0}^{(c)}$	$+\frac{1}{2}[209.51454]$	$+53.571$	$+20.046$	$+8.26978$	$+3.566$	$+1.576$
	$S_{i,0}^{(c)}$		$-.735$	$-.553$	$-.34414$	$-.199$	$-.110$
$\nu=1$	$C_{i,1}^{(c)}$	$+.25653$	$+.548$	$+.382$	$+.22949$	$+.129$	$+.071$
	$S_{i,1}^{(s)}$		$+1.706$	$+1.273$	$+78997$	$+.456$	$+.253$
	$C_{i,1}^{(s)}$	$-.25027$	$-.122$	$-.046$	$-.01129$	$+.002$	$+.005$
	$S_{i,1}^{(c)}$		$+.022$	$+.017$	$+.00807$	$+.003$	$+.001$
$\nu=2$	$C_{i,2}^{(c)}$	$+.00463$	$+.257$	$+.096$	$+.05847$	$+.038$	$+.024$
	$S_{i,2}^{(s)}$		$-.170$	$-.003$	$+.01835$	$+.017$	$+.007$
	$C_{i,2}^{(s)}$	$+.12279$	$+.128$	$+.080$	$+.04667$	$+.026$	$+.015$
	$S_{i,2}^{(c)}$		$+.065$	$+.048$	$+.03063$	$+.018$	$+.010$
$\nu=3$	$C_{i,3}^{(c)}$	$+.03070$	$+.020$	$+.007$	$+.00662$	$+.005$	$+.002$
	$S_{i,3}^{(s)}$		$-.003$	$+.002$	$+.00216$	$+.002$	$+.001$
	$C_{i,3}^{(s)}$	$+.05945$	$+.041$	$+.023$	$+.01319$	$+.006$	$+.003$
	$S_{i,3}^{(c)}$		000	$-.001$	$-.00217$	$-.002$	$-.001$
$\nu=4$	$C_{i,4}^{(c)}$	$+.00037$	$+.001$		$+.00030$		
	$S_{i,4}^{(s)}$		000		$+.00052$		
	$C_{i,4}^{(s)}$	$+.00055$	000		$+.00076$		
	$S_{i,4}^{(c)}$		$-.001$		$-.00103$		

The Quantities $\frac{1}{2}C_{i,v}^{(c)}, \frac{1}{2}C_{i,v}^{(s)}, \frac{1}{2}S_{i,v}^{(c)}, \frac{1}{2}S_{i,v}^{(s)}$, arranged for Quadrature, in the Expansion of

$$\mu\alpha^2\left(\frac{a}{A}\right)^3$$

	$i=0$	$i=1$	$i=2$	$i=3$	$i=4$	$i=5$	$i=6$	$i=7$	$i=8$	$i=9$	
$v=0$	$\left\{\begin{array}{l} C_{i,0}^{(c)} \\ S_{i,0}^{(c)} \end{array}\right.$	$\begin{array}{l} '' \\ +\frac{1}{2}[364.6002] \end{array}$	$\begin{array}{l} '' \\ +246.7810 \end{array}$	$\begin{array}{l} '' \\ +147.068 \end{array}$	$\begin{array}{l} '' \\ +82.9613 \end{array}$	$\begin{array}{l} '' \\ +45.338 \end{array}$	$\begin{array}{l} '' \\ +24.256 \end{array}$	$\begin{array}{l} '' \\ +12.781 \end{array}$	$\begin{array}{l} '' \\ +6.640 \end{array}$	$\begin{array}{l} '' \\ +3.419 \end{array}$	$\begin{array}{l} '' \\ +1.751 \end{array}$
$v=1$	$\left\{\begin{array}{l} C_{i,1}^{(c)} \\ S_{i,1}^{(s)} \\ C_{i,1}^{(s)} \\ S_{i,1}^{(c)} \end{array}\right.$	$\begin{array}{l} +4.3500 \\ \\ -1.8014 \\ +.1015 \end{array}$	$\begin{array}{l} +4.6277 \\ +7.8438 \\ -1.1511 \\ +.1015 \end{array}$	$\begin{array}{l} +3.873 \\ +9.373 \\ -.801 \\ +.104 \end{array}$	$\begin{array}{l} +2.8862 \\ +7.9505 \\ -.3643 \\ +.0731 \end{array}$	$\begin{array}{l} +1.956 \\ +5.816 \\ -.106 \\ +.043 \end{array}$	$\begin{array}{l} +1.253 \\ +3.910 \\ +.017 \\ +.024 \end{array}$	$\begin{array}{l} +.771 \\ +2.488 \\ +.062 \\ +.011 \end{array}$	$\begin{array}{l} +.461 \\ +1.514 \\ +.078 \\ -.008 \end{array}$	$\begin{array}{l} +.270 \\ +.898 \\ +.058 \\ +.003 \end{array}$	$\begin{array}{l} +.154 \\ +.521 \\ +.049 \\ +.001 \end{array}$
$v=2$	$\left\{\begin{array}{l} C_{i,2}^{(c)} \\ S_{i,2}^{(s)} \\ C_{i,2}^{(s)} \\ S_{i,2}^{(c)} \end{array}\right.$	$\begin{array}{l} -.2566 \\ \\ +1.1803 \\ \\ \end{array}$	$\begin{array}{l} +.0899 \\ +.1010 \\ +1.1209 \\ +.3367 \end{array}$	$\begin{array}{l} +.294 \\ +.296 \\ +.883 \\ +.400 \end{array}$	$\begin{array}{l} +.3888 \\ +.3297 \\ +.6281 \\ +.3459 \end{array}$	$\begin{array}{l} +.384 \\ +.302 \\ +.418 \\ +.255 \end{array}$	$\begin{array}{l} +.327 \\ +.239 \\ +.266 \\ +.170 \end{array}$	$\begin{array}{l} +.252 \\ +.173 \\ +.162 \\ +.106 \end{array}$	$\begin{array}{l} +.193 \\ +.116 \\ +.093 \\ +.065 \end{array}$	$\begin{array}{l} +.134 \\ +.078 \\ +.058 \\ +.034 \end{array}$	$\begin{array}{l} +.086 \\ +.047 \\ +.031 \\ -.018 \end{array}$
$v=3$	$\left\{\begin{array}{l} C_{i,3}^{(c)} \\ S_{i,3}^{(s)} \\ C_{i,3}^{(s)} \\ S_{i,3}^{(c)} \end{array}\right.$	$\begin{array}{l} +.1113 \\ \\ +.5132 \\ \\ \end{array}$	$\begin{array}{l} +.1140 \\ -.0170 \\ +.6602 \\ -.0138 \end{array}$	$\begin{array}{l} +.099 \\ .000 \\ +.317 \\ -.030 \end{array}$	$\begin{array}{l} +.0809 \\ +.0059 \\ +.2097 \\ -.0344 \end{array}$	$\begin{array}{l} +.066 \\ +.012 \\ +.130 \\ -.032 \end{array}$	$\begin{array}{l} +.049 \\ +.015 \\ +.076 \\ -.027 \end{array}$	$\begin{array}{l} +.035 \\ +.015 \\ +.043 \\ -.020 \end{array}$	$\begin{array}{l} +.024 \\ +.015 \\ +.020 \\ -.005 \end{array}$	$\begin{array}{l} +.013 \\ +.013 \\ +.012 \\ -.010 \end{array}$	$\begin{array}{l} +.012 \\ +.008 \\ +.002 \\ -.005 \end{array}$
$v=4$	$\left\{\begin{array}{l} C_{i,4}^{(c)} \\ S_{i,4}^{(s)} \\ C_{i,4}^{(s)} \\ S_{i,4}^{(c)} \end{array}\right.$	$\begin{array}{l} +.0177 \\ \\ +.0182 \\ \\ \end{array}$	$\begin{array}{l} +.0085 \\ +.0117 \\ +.0172 \\ -.0109 \end{array}$	$\begin{array}{l} +.003 \\ +.005 \\ +.016 \\ -.022 \end{array}$	$\begin{array}{l} +.0028 \\ +.0061 \\ +.0134 \\ -.0182 \end{array}$	$\begin{array}{l} +.002 \\ +.005 \\ +.010 \\ -.016 \end{array}$	$\begin{array}{l} +.002 \\ +.006 \\ +.006 \\ -.012 \end{array}$	$\begin{array}{l} .000 \\ +.004 \\ +.005 \\ -.008 \end{array}$	$\begin{array}{l} +.001 \\ +.004 \\ +.003 \\ +.002 \end{array}$	$\begin{array}{l} .000 \\ +.001 \\ -.002 \\ -.003 \end{array}$	$\begin{array}{l} +.001 \\ +.001 \\ +.001 \\ -.001 \end{array}$

The quantities $C_{i,\nu}^{(c)}$, $C_{i,\nu}^{(s)}$ etc., of the preceding tables have been divided by 2 to save division after quadrature. To check the values of these coefficients we will take the point corresponding to $g = 22^\circ.5$, using the equation

$$\begin{aligned} A_1^{(c)}, \text{ or } A_1^{(s)} = & \frac{1}{2}C_0 + C_1 \cos g + C_2 \cos 2g + \text{etc.} \\ & + S_1 \sin g + S_2 \sin 2g + \text{etc.}, \end{aligned}$$

noting that the tables give one-half of the values of these quantities.

Thus we have

$i = 1$		$i = 2$	$i = 1$		$i = 2$
$\frac{1}{2}C_{1,0}^{(c)}$	"	"	$\frac{1}{2}S_{1,0}^{(c)}$	"	"
$C_{1,0}^{(c)}$	$= +53.571$	$+20.046$	$S_{1,0}^{(c)}$	$= -0.735$	-0.553
$C_{1,1}^{(c)}$	$= +1.013$	$+ .707$	$S_{1,1}^{(s)}$	$= +1.306$	$+ .974$
$C_{1,1}^{(s)}$	$= - .094$	$- .032$	$S_{1,1}^{(c)}$	$= + .040$	$+ .031$
$C_{1,2}^{(c)}$	$= + .363$	$+ .135$	$S_{1,2}^{(s)}$	$= - .240$	$- .004$
$C_{1,2}^{(s)}$	$= + .181$	$+ .114$	$S_{1,2}^{(c)}$	$= + .092$	$+ .070$
$C_{1,3}^{(c)}$	$= + .015$	$+ .005$	$S_{1,3}^{(s)}$	$= - .005$	$+ .004$
$C_{1,3}^{(s)}$	$= + .077$	$+ .043$	$S_{1,3}^{(c)}$	$= 0$	$- .001$
$C_{1,4}^{(c)}$	$= 0$	$..$	$S_{1,4}^{(s)}$	$= 0$	$..$
$C_{1,4}^{(s)}$	$= 0$	$..$	$S_{1,4}^{(c)}$	$= 0$	$..$
Σ	"	"	Σ	"	"
Σ	$= +55.126$	$+21.018$	Σ	$= +0.458$	$+0.521$
$\frac{1}{8}\Sigma$	$= +6.891$	$+2.627$	$\frac{1}{8}\Sigma$	$= +0.057$	$+0.065$
$A_1^{(c)}$	$= +6.893$	$+2.629$	$A_1^{(s)}$	$= +0.057$	$+0.065$

In this way we check the values of these quantities for all values of i , in case of both $\mu\left(\frac{a}{d}\right)$, and $\mu\alpha^2\left(\frac{a}{d}\right)$.

Applying to the coefficients of the two preceding tables the formula

$$\left(\frac{a}{d}\right)^n = \frac{1}{2}\Sigma\Sigma(C_{i,\nu}^{(c)} \mp S_{i,\nu}^{(s)}) \cos [(i \mp \nu)g - iE'] \mp \frac{1}{2}\Sigma\Sigma(C_{i,\nu}^{(s)} \pm S_{i,\nu}^{(c)}) \sin [(i \mp \nu)g - iE']$$

noting that $\frac{1}{2}$ has been applied, we have the values of $\mu\left(\frac{a}{d}\right)$, $\mu\alpha^2\left(\frac{a}{d}\right)^3$ that follow :

$$\mu \left(\begin{smallmatrix} a \\ j \end{smallmatrix} \right)$$

$$\mu \alpha^2 \left(\begin{smallmatrix} a \\ \Delta \end{smallmatrix} \right)^3$$

$g \ E'$	cos	sin	cos	sin
	"	"	"	"
0 — 0	$+\frac{1}{2}[209.51455]$		$+\frac{1}{2}[364.6002]$	
1 — 0	+0.25653	—0.25027	+4.3500	—1.8014
2 — 0	+0.00463	+0.12279	—0.2566	+1.1803
3 — 0	+0.03070	+0.05945	+0.1113	+0.5132
4 — 0	+0.00037	+0.00055	+0.0177	+0.0182
— 2 — 1	+0.023	—0.041	+0.1310	—0.6464
— 1 — 1	+0.427	—0.193	—0.0112	—1.4577
0 — 1	—1.158	+0.101	—3.2161	+1.0496
1 — 1	+53.571	+0.735	+246.7810	+3.4388
2 — 1	+2.254	—0.144	+12.4716	—1.2526
3 — 1	+0.087	+0.063	+0.1909	+0.7842
4 — 1	+0.016	+0.041	+0.0970	+0.6740
— 1 — 2			+0.099	—0.287
0 — 2	+0.098	—0.129	—0.001	—1.283
1 — 2	—0.891	+0.029	—5.500	+0.697
2 — 2	+20.046	+0.553	+147.068	+4.110
3 — 2	+1.656	—0.063	+13.246	—0.905
4 — 2	+0.093	+0.032	+0.590	+0.483
0 — 3	+0.00446	—0.01101	+0.0750	—0.1753
1 — 3	+0.04011	—0.07730	+0.0591	—0.9741
2 — 3	—0.56048	+0.00322	—5.0643	+0.2912
3 — 3	+8.26978	+0.34414	+82.9613	+3.4992
4 — 3	+1.01947	—0.01936	+10.8367	—0.4375
5 — 3	+0.07682	+0.01603	+0.7185	+0.2822
6 — 3	+0.00879	+0.01536	+0.0868	+0.2441
1 — 4	+0.003	—0.004	+0.053	—0.098
2 — 4	+0.020	—0.044	+0.082	—0.674
3 — 4	—0.326	—0.005	—3.859	+0.062
4 — 4	+3.566	+0.199	+45.338	+2.562
5 — 4	+0.585	—0.001	+7.772	—0.149
6 — 4	+0.055	+0.008	+0.687	+0.163
7 — 4			+0.078	+0.162
2 — 5	+0.005	+0.045	+0.033	—0.049
3 — 5	+0.016	—0.025	+0.088	—0.095
4 — 5	—0.182	—0.007	—2.657	—0.041
5 — 5	+1.576	+0.110	+24.256	+1.722
6 — 5	+0.325	+0.004	+5.163	—0.006
7 — 5	+0.031	+0.004	+0.567	+0.436
4 — 6	+0.009	—0.008	+0.079	—0.269
5 — 6	—0.100	—0.006	—1.717	—0.073
6 — 6	+0.707	+0.060	+12.781	+1.095
7 — 6	+0.176	+0.005	+3.260	+0.050
8 — 6	+0.018	—0.005	+0.426	+0.057

We have next to transform the expressions for $\mu \left(\frac{a}{\Delta}\right)$ and $\mu \alpha^2 \left(\frac{a}{\Delta}\right)^3$ just given into others in which both the angles involved are mean anomalies.

From

$$r_m = \frac{m}{h' \frac{e'}{2}},$$

beginning with $m = 5$, we find the values of r_5 for values of e' from $\frac{e'}{2}$ to e'^4 .

Then we find

$$p_5 = \frac{1}{r_5}.$$

Putting $m = 4$, we find the values of r_4 as in the case of r_5 . Then we get p_4 from

$$p_4 = \frac{1}{r_4 - p_5}.$$

We proceed in this way until we finally have the values of p_1 . Then we find $J_{h' \frac{e'}{2}}^{(0)}$ or $(J_{h' \frac{e'}{2}}^{(0)} - 1)$ from

$$J_{h' \frac{e'}{2}}^{(0)} = 1 - l^2 + \frac{l^4}{4} - \frac{l^6}{36} \pm \text{etc.},$$

where $l = h' \frac{e'}{2}$,

and $J_{h' \frac{e'}{2}}^{(m)}$ from

$$J_{h' \frac{e'}{2}}^{(m)} = J_{h' \frac{e'}{2}}^{(0)} \cdot p_1 \cdot p_2 \cdot p_3 \cdot p_4 \cdot p_5.$$

The details of the computation are as follows:

Computation of the J functions.

$l =$	$\frac{1}{2}e'$	e'	$\frac{3}{2}e'$	$2e'$	$\frac{5}{2}e'$	$3e'$	$\frac{7}{2}e'$	$4e'$
$\log. l$	8.38251	8.68354	8.85963	8.98457	9.08148	9.16066	9.22761	9.28560
$\log. r_5$	2.31646	2.01543	1.83934	1.71440	1.61749	1.53831	1.47136	1.41337
$\log. p_5$	7.68354	7.98457	8.16066	8.28560	8.38251	8.46169	8.52864	8.58663
$\log. r_4$	2.21955	1.91852	1.74243	1.61749	1.52058	1.44140	1.37445	1.31646
$\log. r_1 - \log. p_5$	4.53601	3.93395	3.58177	3.33189	3.13807	2.97971	2.84581	2.72983
Zech	— 1	— 5	— 12	— 20	— 31	— 45	— 62	— 81
	2.21954	1.91847	1.74231	1.61729	1.52027	1.44095	1.37383	1.31585
$\log. p_4$	7.78046	8.08153	8.25769	8.38271	8.47973	8.55905	8.62617	8.68415
$\log. r_3$	2.09461	1.79358	1.61749	1.49255	1.39564	1.31646	1.24951	1.19152
Diff.	4.31415	3.71205	3.35980	3.10984	2.91591	2.75741	2.62334	2.50737
Zech	— 2	— 9	— 19	— 34	— 52	— 76	— 103	— 135
	2.09459	1.79349	1.61730	1.49221	1.39512	1.31570	1.24848	1.19017
$\log. p_3$	7.90541	8.20651	8.38270	8.50779	8.60488	8.68430	8.75152	8.80983
$\log. r_2$	1.91852	1.61749	1.44140	1.31646	1.21955	1.14037	1.07342	1.01543
Diff.	4.01311	3.41098	3.05870	2.80867	2.61467	2.45607	2.32190	2.20560
Zech	— 4	— 17	— 38	— 67	— 105	— 152	— 206	— 269
	1.91848	1.61732	1.44102	1.31579	1.21850	1.13885	1.07136	1.01274
$\log. p_2$	8.08152	8.38268	8.55898	8.68421	8.78150	8.86115	8.92864	8.98726
$\log. r_1$	1.61749	1.31646	1.14037	1.01543	0.91852	0.83934	0.77239	0.71440
Diff.	3.53597	2.93378	2.58139	2.33122	2.13702	1.97819	1.84375	1.72714
Zech	— 13	— 51	— 114	— 202	— 315	— 454	— 618	— 807
	1.61736	1.31595	1.13923	1.01341	0.91537	0.83480	0.76621	0.70633
$\log. p_1$	8.38264	8.68405	8.86077	8.98659	9.08463	9.16520	9.23379	9.29367
$\log. l^1$	3.53004	4.73716	5.43852	5.93828	6.32592	6.64264	6.91044	7.14240
$\log. \frac{l^4}{4}$	2.92798	4.13210	4.83646	5.33622	5.72386	6.04058	6.30838	6.54034
$-\log. l^2$	6.76502 n	7.36708 n	7.71926 n	7.96914 n	8.16296 n	8.32132 n	8.45522 n	8.57120 n
Diff.	3.83704	3.23498	2.88280	2.63292	2.43910	2.28084	2.14684	2.03086
Zech	— 7	— 25	— 57	— 101	— 157	— 227	— 308	— 402
$\log. (-l^2 + \frac{l^4}{4})$	6.76495 n	7.36693 n	7.71869 n	7.96813 n	8.16139 n	8.31905 n	8.45214 n	8.56718 n
Zech	— 26	— 101	— 227	— 401	— 625	— 896	— 1213	— 1575
$\log. J^{(0)}$	9.99974	9.99899	9.99773	9.99599	9.99375	9.99104	9.98787	9.98425
$\log. p_1$	8.38264	8.68405	8.86077	8.98659	9.08463	9.16520	9.23379	9.29367
$\log. J^{(1)}$	8.38238	8.68304	8.85850	8.98258	9.07838	9.15624	9.22166	9.27792
$\log. p_2$	8.08152	8.38268	8.55898	8.68421	8.78150	8.86115	8.92864	8.98726
$\log. J^{(2)}$	6.46390	7.06572	7.41748	7.66679	7.85988	8.01739	8.15030	8.26518
$\log. p_3$	7.90541	8.20651	8.38270	8.50779	8.60488	8.68430	8.75152	8.80983
$\log. J^{(3)}$	4.36931	5.27223	5.80018	6.17458	6.46476	6.70169	6.90182	7.07501
$\log. p_4$	7.78046	8.08153	8.25769	8.38271	8.47973	8.55905	8.62617	8.68415
$\log. J^{(4)}$	2.14977	3.35376	4.05787	4.55729	4.94449	5.26074	5.52799	5.75916

Noting that $\log. (J^{(0)} - 1) = \log. \left(-l^2 + \frac{l^4}{4}\right)$, $\lambda' = \frac{e'}{2}$, and $l = h'\lambda'$, we form the following tables :

h'	$\text{Log.} \frac{1}{h'} (J_{h'\lambda'}^{(0)} - 1)$	$\text{Log.} \frac{1}{h'} J_{h'\lambda'}^{(1)}$	$\text{Log.} \frac{1}{h'} J_{h'\lambda'}^{(2)}$	$\text{Log.} \frac{1}{h'} J_{h'\lambda'}^{(3)}$	$\text{Log.} \frac{1}{h'} J_{h'\lambda'}^{(4)}$
1	6.7649 <i>n</i>	8.38238	6.4639	4.3693	2.1498
2	7.0658 <i>n</i>	8.38201	6.7647	4.9712	3.0527
3	7.2415 <i>n</i>	8.38138	6.9404	5.3231	3.5807
4	7.3661 <i>n</i>	8.38052	7.0647	5.5725	3.9551
5	7.4624 <i>n</i>	8.37941	7.1610	5.7658	4.2456
6	7.5409 <i>n</i>	8.37809	7.2392	5.9235	4.4826
7	7.6070 <i>n</i>	8.37656	7.3052	6.0567	4.6828
8	7.6641 <i>n</i>	8.37483	7.3621	6.1719	4.8562

Value of $\frac{i'}{h'} J_{h'\lambda'}^{(h'-i')}$

i'	$h'=-2$	$h'=-1$	$h'=+1$	$h'=2$	$h'=3$	$h'=4$	$h'=5$	$h'=6$	$h'=7$	$h'=8$
1	4.9712 <i>n</i>	6.4639 <i>n</i>	6.76495 <i>n</i>	8.38201	6.9404	5.5725	4.2455	....	....	....
2	3.3537 <i>n</i>	4.6703 <i>n</i>	8.68341 <i>n</i>	7.36693 <i>n</i>	8.68241	7.3657	6.0668	4.7835	....	....
3			6.9410	8.85913 <i>n</i>	7.71869 <i>n</i>	8.85764	7.6381	6.4006	5.1598	....
4			4.9714 <i>n</i>	7.36675	8.98344 <i>n</i>	7.96813 <i>n</i>	8.98147	7.8413	6.6588	5.4583
5				5.6702 <i>n</i>	7.6393	9.07949 <i>n</i>	8.1614 <i>n</i>	9.07706	8.0042	6.8709
6					6.1012 <i>n</i>	7.8432	9.15756 <i>n</i>	8.3190 <i>n</i>	9.15471	8.1402
7	For $h'=0$,					6.4176 <i>n</i>	8.0061	9.22320 <i>n</i>	8.4521 <i>n</i>	9.21993
8	we have						6.6689 <i>n</i>	8.1423	9.27965 <i>n</i>	8.5672 <i>n</i>
9								6.8777 <i>n</i>	8.2594	9.32905 <i>n</i>

In computing the values of the J functions, the lines headed Zech show that addition or subtraction tables have been used. For convenience, $(J^{(0)} - 1)$ is employed instead of $J^{(0)}$, its values being found in the line headed $\log. \left(-l^2 + \frac{l^4}{4}\right)$.

From the expression

$$((i, h')) = \sum \frac{i'}{h'} J_{h'\lambda'}^{(h'-i')} (i, i'),$$

h' being the multiple of g' , and being constant, and i' being variable, we have

$$\begin{aligned} ((i, h')) &= \frac{1}{h'} J_{h'\lambda'}^{(h'-1)} \cos \sin (ig - E') + \frac{2}{h'} J_{h'\lambda'}^{(h'-2)} \cos \sin (ig - 2E') + \text{etc.} \\ &\quad - \frac{1}{h'} J_{h'\lambda'}^{(h'+1)} \cos \sin (ig + E') - \frac{2}{h'} J_{h'\lambda'}^{(h'+2)} \cos \sin (ig + 2E') - \text{etc.} \end{aligned}$$

Now for $h' = +1$, we have, if we write the angle in place of the coefficient,

$$\begin{aligned} ((ig - g')) &= \frac{1}{1} J_{\lambda'}^{(0)} \cos \sin (ig - E') + \frac{2}{1} J_{\lambda'}^{(-1)} \cos \sin (ig - 2E') + \text{etc.} \\ &\quad - \frac{1}{1} J_{\lambda'}^{(2)} \cos \sin (ig + E') - \frac{2}{1} J_{\lambda'}^{(3)} \cos \sin (ig + 2E') - \text{etc.}; \end{aligned}$$

and for $h' = -1$, we have

$$\begin{aligned} ((ig + g')) &= -\frac{1}{1} J_{-\lambda'}^{(-2)} \cos \sin (ig - E') - \frac{2}{1} J_{-\lambda'}^{(-3)} \cos \sin (ig - 2E') - \text{etc.} \\ &\quad + \frac{1}{1} J_{-\lambda'}^{(0)} \cos \sin (ig + E') + \frac{2}{1} J_{-\lambda'}^{(1)} \cos \sin (ig + 2E') + \text{etc.} \end{aligned}$$

Since

$$J_{h'}^{(-m)} = (-1)^m J_{h'}^{(m)}, \quad J_{-h'}^{(m)} = (-1)^m J_{h'}^{(m)}, \quad J_{-h'}^{(-m)} = J_{h'}^{(m)},$$

the last two expressions give

$$\begin{aligned} ((ig - g')) &= J_{\lambda'}^{(0)} \cos \sin (ig - E') - 2J_{\lambda'}^{(1)} \cos \sin (ig - 2E') \pm \text{etc.} \\ &\quad - J_{\lambda'}^{(2)} \cos \sin (ig + E') - 2J_{\lambda'}^{(3)} \cos \sin (ig + 2E') - \text{etc.}, \\ ((ig + g')) &= -J_{\lambda'}^{(2)} \cos \sin (ig - E') - 2J_{\lambda'}^{(3)} \cos \sin (ig - 2E') - \text{etc.} \\ &\quad + J_{\lambda'}^{(0)} \cos \sin (ig + E') - 2J_{\lambda'}^{(1)} \cos \sin (ig + 2E') \pm \text{etc.} \end{aligned}$$

And for the particular case of $i = 1$, we have

$$\begin{aligned}
 ((g - g')) &= J_{\lambda'}^{(0)} \cos \sin (g - E') - 2J_{\lambda'}^{(1)} \cos \sin (g - 2E') + 3J_{\lambda'}^{(2)} \cos \sin (g - 3E') \mp \text{etc.} \\
 &\quad - J_{\lambda'}^{(2)} \cos \sin (g + E') - 2J_{\lambda'}^{(3)} \cos \sin (g + 2E') - 3J_{\lambda'}^{(4)} \cos \sin (g + 3E') - \text{etc.} \\
 ((g + g')) &= -J_{\lambda'}^{(2)} \cos \sin (g - E') - 2J_{\lambda'}^{(3)} \cos \sin (g - 2E') - 3J_{\lambda'}^{(4)} \cos \sin (g - 3E') - \text{etc.} \\
 &\quad + J_{\lambda'}^{(0)} \cos \sin (g + E') - 2J_{\lambda'}^{(1)} \cos \sin (g + 2E') + 3J_{\lambda'}^{(2)} \cos \sin (g + 3E') \mp \text{etc.}
 \end{aligned}$$

Instead of $J_{\lambda'}^{(0)}$, we use $(J_{\lambda'} - 1)$, as has been noted.

If we put $h' = +2$, we have

$$\begin{aligned}
 ((ig - 2g')) &= \frac{1}{2} J_{2\lambda'}^{(1)} \cos \sin (ig - E') + \frac{2}{2} J_{2\lambda'}^{(0)} \cos \sin (ig - 2E') + \frac{3}{2} J_{2\lambda'}^{(-1)} \cos \sin (ig - 3E') + \text{etc.} \\
 &\quad - \frac{1}{2} J_{2\lambda'}^{(3)} \cos \sin (ig + E') - \frac{2}{2} J_{2\lambda'}^{(4)} \cos \sin (ig + 2E') - \text{etc.}
 \end{aligned}$$

In the table giving the values of $\frac{i'}{h'} J_{h'\lambda'}^{(h'-i')}$, we have, under $h' = 2$, which applies to the equation just given,

$$\begin{aligned}
 \text{for } i' = 1, & \quad \log. \frac{1}{2} J_{2\lambda'}^{(1)} = 8.38201 & \log. (-\frac{1}{2} J_{2\lambda'}^{(3)}) = 4.9712n; \\
 \text{for } i' = 2, & \quad \log. (\frac{2}{2} J_{2\lambda'}^{(0)} - 1) = 7.36693n & \log. (-\frac{2}{2} J_{2\lambda'}^{(4)}) = 3.3537n; \\
 \text{for } i' = 3, & \quad \log. (-\frac{3}{2} J_{2\lambda'}^{(1)}) = 8.85913n & \text{etc.} = \text{etc.} \\
 \text{etc.,} & \quad \text{etc.} = \text{etc.}
 \end{aligned}$$

We find the values of $-\frac{1}{2} J_{2\lambda'}^{(3)}$, $-\frac{2}{2} J_{2\lambda'}^{(4)}$ in the table under $h' = -2$. We see that these are the forms of the function $\frac{i'}{h'} J_{h'\lambda'}^{(h'-i')}$ when $h = -2$, and $i' = 1$ and $i' = 2$.

In the expansion of the coefficient of $(ig - h'g')$ indicated above by $((ig - h'g'))$, we have coefficients of angles of the form $(ig + i'E')$. These can readily be put into the form $(-ig - i'E')$, but the form employed is convenient in the transformation.

Arranging the functions $\mu\left(\frac{a}{\Delta}\right)$, $\mu\alpha^2\left(\frac{a}{\Delta}\right)^3$ in this form, we have

Log. $\mu\left(\frac{a}{\Delta}\right)$		Log. $\mu\alpha^2\left(\frac{a}{\Delta}\right)^3$		
g	E'	cos	sin	
0	— 1	0.0637 n	9.0043	0.5074 n
0	— 2	8.9912	9.1106 n	7.0000 n
0	— 3	7.6493	8.0418 n	8.8751
1	+ 1	9.6304	9.2856	8.0493
1	— 1	1.72893	9.8663	2.3923
1	— 2	9.9499 n	8.4624	0.7404 n
1	— 3	8.6032	8.8882 n	8.7716
1	— 4	7.4771	7.6021 n	8.7243
2	+ 1	8.3617	8.6128	9.1173
2	— 1	0.3530	9.1584 n	1.0959
2	— 2	1.30203	9.7427	2.1675
2	— 3	9.7486 n	7.5079	0.7045 n
2	— 4	8.3010	8.6435 n	8.9138
2	— 5	6.6990	7.6532	
3	— 1	8.9395	8.7993	9.2808
3	— 2	0.2191	8.7993 n	1.1221
3	— 3	0.91750	9.5368	1.9189
3	— 4	9.5132 n	7.6990 n	0.5865 n
3	— 5	8.2041	8.3979 n	8.9445
4	— 1	8.2041	8.6128	8.9868
4	— 2	8.9685	8.5051	9.7709
4	— 3	0.0082	8.2869 n	1.0348
4	— 4	0.5522	9.2989	1.6565
4	— 5	9.2601 n	7.8451 n	0.4244 n
4	— 6	7.9542	7.9093 n	8.8976
5	— 3	8.8855	8.2049	9.8564
5	— 4	9.7672	7.0000 n	0.8905
5	— 5	0.1976	9.0414	1.3848
5	— 6	9.0000 n	7.7782 n	0.2347 n
6	— 3	7.9440	8.1864	8.9385
6	— 4	8.7404	7.9031	9.8370
6	— 5	9.5119	7.6021	0.7129
6	— 6	9.8494	8.7782	1.1066
6	— 7			0.0224 n
7	— 6			0.5132
7	— 7			0.8222
7	— 8			9.7973 n

We will now give examples to illustrate the application of the tables for transforming from eccentric to mean anomaly, in case of the function $\mu\left(\frac{a}{\Delta}\right)$.

For the angle $3g - 3g'$.

$\mu\left(\frac{a}{\Delta}\right)$		$\frac{i'}{h'} J_{h'\lambda'}^{(h'-i')}$					
g	E'	cos	sin	$(h' = 3)$	Log. Product.		Product.
						"	"
3 — 1		8.9395	8.7993	6.9404	5.8799	5.7397	+ .00008 + .00005
3 — 2		0.2191	8.7993 <i>n</i>	8.68241	8.9015	7.6817 <i>n</i>	+ .07970 — .00303
3 — 3		0.91750	7.5368	7.71869 <i>n</i>	8.6362 <i>n</i>	5.2555 <i>n</i>	— .04327 — .00180
3 — 4		9.5132 <i>n</i>	7.6990 <i>n</i>	8.98344 <i>n</i>	8.4966	6.6824	+ .03139 + .00048
3 — 5		8.2041	8.3979 <i>n</i>	7.6393	5.8434	6.0372 <i>n</i>	+ .00007 — .00011
							+8.26978 +0.34414
							+8.33775 +0.33973

For the angle $g - og'$.

				$(h' = 0)$			
						"	"
1 — 1		1.72893	9.8663	8.38251 <i>n</i>	0.11144 <i>n</i>	8.2488 <i>n</i>	—1.29259 + .01773
1 + 1		9.6304	9.2856	8.38251 <i>n</i>	8.0129 <i>n</i>	7.6681 <i>n</i>	— .01030 — .00466
							+0.25653 —0.25027
							—1.04636 —0.27266

For the angle $g + g'$.

				$(h' = -1)$			
						"	"
1 — 1		1.7289	9.8663	6.4639 <i>n</i>	8.1928 <i>n</i>	6.3302 <i>n</i>	— .016 .000
							+0.427 +0.193
							+0.411 +0.193

For the angle $og - og'$.

0 — 1	0.0637 <i>n</i>	....	8.3825 <i>n</i>	8.4462	...	+	.02794	....
							+104.75727	....
								=====
								+104.78521
								=====

For the angles represented by $(ig - g')$, there may be cases when there are sensible terms arising from $g + E'$, $g + 2E'$, etc.; if so, we use the column for $h' = -1$, and apply the proper numbers of this column to the coefficients of the angles named. Likewise in the case of $(ig + g')$, there may be terms arising from the product of the numbers in the column $h' = 1$ and the coefficients of the angles $g + E'$, etc. This will be made clear by an inspection of the two expressions

$$((ig - g')) = J_{\lambda'}^{(0)} \frac{\cos}{\sin} (ig - E') - 2J_{\lambda'}^{(1)} \frac{\cos}{\sin} (ig - 2E') \pm \text{etc.}$$

$$- J_{\lambda'}^{(2)} \frac{\cos}{\sin} (ig + E') - 2J_{\lambda'}^{(3)} \frac{\cos}{\sin} (ig - 2E') - \text{etc.},$$

$$((ig + g')) = - J_{\lambda'}^{(2)} \frac{\cos}{\sin} (ig - E') - 2J_{\lambda'}^{(3)} \frac{\cos}{\sin} (ig - 2E') - \text{etc.}$$

$$+ J_{\lambda'}^{(0)} \frac{\cos}{\sin} (ig + E') - 2J_{\lambda'}^{(1)} \frac{\cos}{\sin} (ig + 2E') \pm \text{etc.};$$

where $((ig - g'))$, $((ig + g'))$ represent not the angles but their coefficients.

In retaining the form $(ig + i'E')$ instead of the form $(-ig - i'E')$ we can perform the operations indicated without any change of sign in case of the sine terms.

Making the transformations as indicated above, we obtain the following expressions for the functions $\mu\left(\frac{a}{d}\right)$, and $\mu\alpha^2\left(\frac{a}{d}\right)^3$:

$$\mu \left(\frac{a}{\Delta} \right)$$

$$\mu \alpha^2 \left(\frac{a}{\Delta} \right)^3$$

$g \quad g'$	cos	sin	cos	sin
	"		"	
0 — 0	+104.78521	"	+182.3777	"
1 — 0	— 1.04636	—0.27266	— 1.6046	—1.9194
2 — 0	— 0.05031	+0.12527	— 0.5606	+1.1949
3 — 0	+ 0.02860	+0.05793	+ 0.1067	+0.4943
—2 — 1			— 0.1274	—0.6468
—1 — 1	+ 0.411	—0.193	— 0.0830	—1.4558
0 — 1	— 1.162	+0.107	— 3.2141	+1.1107
1 — 1	+ 53.583	+0.734	+246.9027	+3.4023
2 — 1	+ 1.286	—0.171	+ 5.3656	—1.4496
3 — 1	+ 0.014	+0.066	— 0.3758	+0.8304
0 — 2	+ 0.070	—0.127	— 0.085	—1.242
1 — 2	+ 0.399	+0.053	+ 0.456	+0.848
2 — 2	+ 20.093	+0.551	+147.392	+4.049
3 — 2	+ 1.056	—0.086	+ 7.214	—1.137
4 — 2	+ 0.027	+0.033	— 0.086	+0.537
0 — 3	+ 0.00815	—0.01707	+ 0.0718	—0.2352
1 — 3	+ 0.04342	—0.07447	+ 0.0041	—0.9231
2 — 3	+ 0.40733	+0.03392	+ 2.0442	+0.5514
3 — 3	+ 8.338	+0.340	+ 83.537	+3.432
4 — 3	+ 0.675	—0.036	+ 6.432	—0.659
5 — 3	+ 0.028	+0.010	+ 0.079	+0.449
2 — 4	+ 0.027	—0.043	+ 0.050	—0.637
3 — 4	+ 0.275	+0.023	+ 2.174	+2.592
4 — 4	+ 3.628	+0.197	+ 46.016	+2.512
5 — 4	+ 0.397	—0.013	+ 4.828	—0.323
6 — 4	+ 0.021	+0.008	+ 0.156	+0.188
3 — 5	+ 0.020	—0.023	+ 0.080	—0.074
4 — 5	+ 0.167	+0.012	+ 1.762	+0.241
5 — 5	+ 1.623	+0.109	+ 24.829	+1.565
6 — 5	+ 0.224	—0.004	+ 3.306	—0.148
4 — 6	+ 0.012	—0.008	+ 0.077	—0.250
5 — 6	+ 0.092	+0.007	— 4.535	+0.150
6 — 6	+ 0.731	+0.059	+ 13.312	+1.085

The transformation should be carefully checked by being done in duplicate, or better by putting the angle $ig = 0$, in all the divisions of the two functions, having thus only the angles $(0 - E')$, $(0 - 2E')$, $(0 - 3E')$, etc., etc.; also $(0 - g')$, $(0 - 2g')$, etc. Adding the coefficients in each division of the functions before and after transformation, and operating on the sums before transformation as on single members of the sums, the results should agree with the sums of the divisions of the transformations given above.

The transformations of these functions were checked by being done in duplicate, but we will give the check in case of another planet. We have for the logarithms of the sums before transformation, and for the sums after transformation the following:

$g - E'$	cos	sin	$g - g'$	cos	sin
0 — 1	1.85407	1.62090 <i>n</i>	0 — 1	+ 70.548	— 40.188
0 — 2	1.25778	1.51473 <i>n</i>	0 — 2	+ 19.809	— 32.318
0 — 3	9.7024 <i>n</i>	1.26993 <i>n</i>	0 — 3	+ 0.906	— 19.352
0 — 4	0.7101 <i>n</i>	0.9147 <i>n</i>	0 — 4	— 4.540	— 9.263
0 — 5	0.6632 <i>n</i>	0.3899 <i>n</i>	0 — 5	— 4.707	— 3.313
0 — 6	0.4387 <i>n</i>	9.0934	0 — 6	— 3.059	— 0.330
0 — 7	0.1222 <i>n</i>	9.8069	0 — 7	— 0.623	+ 0.739
0 — 8	9.5965 <i>n</i>	9.8865	0 — 8	— 0.071	+ 0.615

For the angle $(0 - 1)$,		$(0 - 2)$,		$0 - 3$.	
<u>0.041</u>	<u>+ 0.024</u>	<u>+ 1.722</u>	<u>— 1.007</u>	<u>+ .062</u>	<u>— .037</u>
0.873	+ 1.578	— .042	+ .076	+ .871	— 1.574
.000	— 0.016	+ .037	+ 1.346	+ .003	+ .097
<u>+ 71.462</u>	<u>— 41.774</u>	— .012	— .019	+ .494	+ .791
+ 70.548	— 40.188	<u>+ 18.104</u>	<u>— 32.714</u>	— .020	— .011
+ 70.573	— 40.196	<u>+ 19.809</u>	<u>— 32.318</u>	— .504	— 18.618
		<u>+ 19.811</u>	<u>— 32.319</u>	<u>+ 0.906</u>	<u>+ 19.352</u>
				<u>+ 0.902</u>	<u>— 19.355</u>

The numbers in the last line of each case are the sums of the divisions after conversion when ig is put = 0.

To have close agreement it is necessary that all sensible terms in the expansion of $\mu\left(\frac{a}{j}\right)$ and $\mu\alpha^2\left(\frac{a}{j}\right)^3$ be retained. In the expressions for these functions given a large number of terms and some groups of terms have been omitted as they produce no terms in the final results of sufficient magnitude to be retained.

In transforming a series it will be convenient to have the values of the J functions on a separate slip of paper, so that by folding the slip vertically we can form the products at once without writing the separate factors.

The numerical expressions for $\mu\left(\frac{a}{j}\right)$ and $\mu\alpha^2\left(\frac{a}{j}\right)^3$ being known, we need next to have those designated by (II) and (I), which represent the action of the disturbing body on the Sun.

To find (H) we use two methods to serve as checks. We have first

$$\begin{aligned}
 (H) = & \frac{1}{2}[h\gamma_1\gamma_1' + h'\delta_1\delta_1'] \cos(g - g') - \frac{1}{2}[l\delta_1\gamma_1' + l'\gamma_1\delta_1'] \sin(g - g') \\
 & + \frac{1}{2}[h\gamma_1\gamma_1' - h'\delta_1\delta_1'] \cos(-g - g') - \frac{1}{2}[l\delta_1\gamma_1' - l'\gamma_1\delta_1'] \sin(-g - g') \\
 & + \frac{1}{2} h\gamma_0\gamma_1' \cos(-g') - \frac{1}{2} l'\gamma_0\delta_1' \sin(-g') \\
 & + 2[h\gamma_1\gamma_2' + h'\delta_1\delta_2'] \cos(g - 2g') - 2[l\delta_1\gamma_2' + l'\gamma_1\delta_2'] \sin(g - 2g') \\
 & + 2[h\gamma_1\gamma_2' - h'\delta_1\delta_2'] \cos(-g - 2g') - 2[l\delta_1\gamma_2' - l'\gamma_1\delta_2'] \sin(-g - 2g') \\
 & + 2 h\gamma_0\gamma_2' \cos(-2g') - 2 l'\gamma_0\delta_2' \sin(-2g') \\
 & + \frac{3}{2}[h\gamma_1\gamma_3' + h'\delta_1\delta_3'] \cos(g - 3g') - \frac{3}{2}[l\delta_1\gamma_3' + l'\gamma_1\delta_3'] \sin(g - 3g') \\
 & + \text{etc.}
 \end{aligned}$$

where

$$\begin{aligned}
 \gamma_1 &= J_\lambda^{(0)} - J_\lambda^{(2)} & \delta_1 &= J_\lambda^{(0)} + J_\lambda^{(2)} \\
 \gamma_2 &= \frac{1}{2}[J_{2\lambda}^{(1)} - J_{2\lambda}^{(3)}] & \delta_2 &= \frac{1}{2}[J_{2\lambda}^{(1)} + J_{2\lambda}^{(3)}] \\
 \gamma_3 &= \frac{1}{8}[J_{3\lambda}^{(2)} - J_{3\lambda}^{(4)}] & \delta_3 &= \frac{1}{8}[J_{3\lambda}^{(2)} + J_{3\lambda}^{(4)}],
 \end{aligned}$$

and similar expressions for $\gamma_1', \delta_1', \gamma_2', \delta_2', \text{etc.}$; noting that $\gamma_0 = -3e$.

The other expression for (H) is

$$\begin{aligned}
 (H) = & \frac{1}{2}[h\gamma_1' - h'\delta_1'] \cos(-E - g') + \frac{1}{2}[l\gamma_1' - l'\delta_1'] \sin(-E - g') \\
 & + \frac{1}{2}[h\gamma_1' + h'\delta_1'] \cos(E - g) - \frac{1}{2}[l\gamma_1' + l'\delta_1'] \sin(E - g') \\
 & - eh\gamma_1' \cos(-g') + el'\delta_1' \sin(-g') \\
 & + 2[h\gamma_2' - h'\delta_2'] \cos(-E - 2g') + 2[l\gamma_2' - l'\delta_2'] \sin(-E - 2g') \\
 & + 2[h\gamma_2' + h'\delta_2'] \cos(E - 2g') - 2[l\gamma_2' + l'\delta_2'] \sin(E - 2g') \\
 & - 4eh\gamma_2' \cos(-2g') + 4el'\delta_2' \sin(-2g') \\
 & + \text{etc.} \qquad \qquad \qquad + \text{etc.}
 \end{aligned}$$

In both expressions for (H) we have

$$h = \frac{\mu}{a^2} k \cos(\Pi - K)$$

$$h' = \frac{\mu}{a^2} \cos \phi \cos \phi' k_1 \cos(\Pi - K_1) = \frac{1}{2} \mu \frac{v \cos V}{a^3}$$

$$l = \frac{\mu}{a^2} \cos \phi k \sin(\Pi - K) = \frac{1}{2} \mu \frac{v \sin V}{a^3}$$

$$l' = \frac{\mu}{a^2} \cos \phi' k_1 \sin(\Pi - K) = \frac{1}{2} \mu \frac{p \cos P}{a^3}$$

where as before

$$\mu = \frac{m'}{1+m} \cdot 206264.''8 \quad \text{and} \quad \alpha = \frac{a'}{a}.$$

In the second expression the eccentric angle of the disturbed body appears and we must transform the expression into one in which both angles are mean anomalies. With the eccentricity, e , of the disturbed body we compute the J functions just as we did in case of e' of the disturbing body.

We have in case of Althæa

	$\frac{1}{2}e$	e	$\frac{3}{2}e$	$2e$
Log. $J^{(0)} - 1$	= 7.20740 n	7.80894 n	8.16025 n	8.40890 n
Log. $J^{(0)}$	= 9.99930	9.99719	9.99368	9.98872
Log. $J^{(1)}$	= 8.60344	8.90341	9.07774	9.20016
Log. $J^{(2)}$	= 6.90632	7.5077	7.8587	8.1068
Log. $J^{(3)}$	= 5.0329	5.9356	6.4630	6.8365
Log. $J^{(4)}$	= 3.0347	4.2384	4.9418	5.4403

From these values we may form a table of $i \frac{(h-i)}{h} J_{h\lambda}$ as was done for the disturbing body. The values of these quantities can be checked by means of the tables found in ENGELMANN'S edition of BESSEL'S *Werke*, Band I, pp. 103-109.

Finding the numerical value of (H) first by the second expression, we get

$E \quad g'$	cos	sin
	''	''
1 — 1	+48.154	+0.651
—1 — 1	+ 0.188	—0.102
0 — 1	3.884	—0.044
1 — 2	+ 4.644	+0.062
—1 — 2	+ 0.018	—0.010
0 — 2	— 0.374	—0.004
1 — 3	+ 0.37800	+0.00510
—1 — 3	+ 0.00141	—0.00081
0 — 3	— 0.03048	—0.00036

To transform we change from $(hE - i'g')$ into $(i'g' - hE)$. Making the transformation, writing also the values found from the first expression for the sake of comparison, and the value of (I) which will next be determined, we have

(H)				(I)			
g	g'	cos "	sin "	cos "	sin "	sin "	cos "
0	— 1	— 5.826	—0.066	— 5.824	—0.066	+4.799	+2.043
0	— 2	— 0.560	—0.006	— 0.562	—0.006	+0.463	+0.197
0	— 3	— 0.04566	—0.00057	— 0.04575	...	+0.038	+0.016
—1	— 1	+ 0.149	—0.103	+ 0.180	—0.103		
1	— 1	+48.076	+0.650	+48.079	+0.650		
1	— 2	+ 4.637	+0.062	+ 4.605	+0.062		
1	— 3	+ 0.37740	+0.00502	+ 0.37738	+0.00510		
2	— 1	+ 1.927	+0.026	+ 1.927	+0.030		
2	— 2	+ 0.186	+0.002	+ 0.186	+0.002		
2	— 3	+ 0.011	0.000	+ 0.015	0.000		

To find the numerical value of (I) needed in case of the function $a^2 \left(\frac{d\Omega}{dz} \right)$, we have

$$\begin{aligned}
 (I) = & \quad b\delta'_1 \sin(-g') + b'\gamma'_1 \cos(-g') \\
 & + 4b\delta'_2 \sin(-2g') + 4b'\gamma'_2 \cos(-2g') \\
 & + 9b\delta'_3 \sin(-3g') + 9b'\gamma'_3 \cos(-3g') \\
 & + \text{etc.} \qquad \qquad \qquad + \text{etc.}
 \end{aligned}$$

where

$$b = -\frac{\mu}{a^2} \cos \phi' \sin I \cos \Pi', \quad b' = \frac{\mu}{a^2} \sin I \sin \Pi'.$$

Having the values of $\mu \left(\frac{a}{\Delta} \right)$, $\mu a^2 \left(\frac{a}{\Delta} \right)^3$, (H) , and (I) , we next find those of

$$a\Omega, \quad ar \frac{d\Omega}{dr}, \quad \text{and} \quad a^2 \frac{d\Omega}{dz},$$

from

$$a\Omega = \mu \left(\frac{a}{d} \right) - (H)$$

$$ar \frac{d\Omega}{dr} = \frac{1}{2} \mu \alpha^2 \left(\frac{a}{d} \right)^3 \left[\frac{r'^2}{a'^2} - \frac{1}{a^2} \frac{r^2}{a^2} \right] - \frac{1}{2} \mu \left(\frac{a}{d} \right) - (H)$$

$$a^2 \frac{d\Omega}{dz} = -\mu \alpha^2 \left(\frac{a}{d} \right)^3 \frac{\sin I}{a} \cdot \frac{r'}{a'} \sin (f' + \Pi') + (I)$$

where

$$\frac{r^2}{a^2} = 1 + \frac{3}{2}e^2 - \frac{4}{1}J_{\lambda}^{(1)} \cos g - \frac{4}{4}J_{2\lambda}^{(2)} \cos 2g - \frac{4}{9}J_{3\lambda}^{(3)} \cos 3g - \text{etc.}$$

$$-\frac{\sin I}{a} \frac{r'}{a'} \sin (f' + \Pi') = -[J_{\lambda'}^{(0)} + J_{\lambda'}^{(2)}] c_1 \sin g' - \frac{1}{2}[J_{2\lambda'}^{(1)} + J_{2\lambda'}^{(3)}] c_1 \sin 2g' - \text{etc.}$$

$$+ \frac{3}{2}e'c_2 - [J_{\lambda'}^{(0)} - J_{\lambda'}^{(2)}] c_2 \cos g' - \frac{1}{2}[J_{2\lambda'}^{(1)} - J_{2\lambda'}^{(3)}] c_2 \cos 2g' - \text{etc.}$$

c_1 and c_2 being given by the equations

$$c_1 = \frac{\sin I}{a} \cos \phi' \cos \Pi'$$

$$c_2 = \frac{\sin I}{a} \sin \Pi'.$$

We find

$$\frac{1}{2} \left[\frac{r'^2}{a'^2} - \frac{1}{a^2} \frac{r^2}{a^2} \right] = [9.5769400] - 2[8.38238] \cos g' - 2[6.46366] \cos 2g' - \text{etc.}$$

$$+ 2[7.99450] \cos g + 2[6.29667] \cos 2g + \text{etc.}$$

$$-\frac{\sin I}{a} \frac{r'}{a'} \sin (f' + \Pi') = [7.18046] + 2[8.39074] \sin g' + 2[6.77809] \sin 2g'$$

$$- 2[8.01941] \cos g' - 2[6.40668] \cos 2g'$$

In multiplying two trigonometric series together, called by HANSEN mechanical multiplication,

let α_λ the coefficients of the angles λx in case of the sine,
 β_μ those of the angles μx in case of the cosine,
 γ_ν those of the angles νy in case of the sine,
 and δ_ρ those of the angles ρy in case of the cosine.

The following cases then occur :

$$\alpha_\lambda \sin \lambda x \cdot \delta_\rho \cos \rho y = \frac{1}{2} \alpha_\lambda \delta_\rho \sin (\lambda x + \rho y) + \frac{1}{2} \alpha_\lambda \delta_\rho \sin (\lambda x - \rho y)$$

$$\beta_\mu \cos \mu x \cdot \gamma_\nu \sin \nu y = \frac{1}{2} \beta_\mu \gamma_\nu \sin (\mu x + \nu y) - \frac{1}{2} \beta_\mu \gamma_\nu \sin (\mu x - \nu y)$$

$$\beta_\mu \cos \mu x \cdot \delta_\rho \cos \rho y = \frac{1}{2} \beta_\mu \delta_\rho \cos (\mu x + \rho y) + \frac{1}{2} \beta_\mu \delta_\rho \cos (\mu x - \rho y)$$

$$\alpha_\lambda \sin \lambda x \cdot \gamma_\nu \sin \nu y = -\frac{1}{2} \alpha_\lambda \gamma_\nu \cos (\lambda x + \nu y) + \frac{1}{2} \alpha_\lambda \gamma_\nu \cos (\lambda x - \nu y).$$

In every term of the second members the factor $\frac{1}{2}$ occurs. Hence before multiplying we resolve the coefficients of one of the factors into two terms, one of which is 2. Performing the operations indicated, we have the values of $a\Omega$, $a r \frac{d\Omega}{dr}$, $a^2 \frac{d\Omega}{dz}$ that follow :

		$a\Omega$		$ar\left(\frac{d\Omega}{dr}\right)$		$a^2\left(\frac{d\Omega}{dz}\right)$	
g	g'	cos	sin	cos	sin	cos	sin
		"	"	"	"	"	"
0 — 0		+104.78521	.....	+16.5202	.....	+0.2828	.....
1 — 0		— 1.04636	— .27266	— 2.4398	— .6940	— 2.6311	+6.0177
2 — 0		— .05031	+ .12527	— .3040	+ .3928	— .059	+ .239
3 — 0		+ .02860	+ .05793	+ .0274	+ .1494	— .017	— .017
—1 — 1		+ .231	— .090	— .431	— .355	.000	— .129
0 — 1		+ 4.662	+ .173	— 1.166	+ .481	— 1.743	— 4.157
1 — 1		+ 5.504	+ .084	+ 18.839	+ .190	+ .318	+ .068
2 — 1		— .641	— .201	— 1.652	— .577	— 1.596	+ 3.580
3 — 1		+ .014	+ .066	— .240	+ .288	— .059	+ .232
0 — 2		+ .632	— .121	+ .497	— .414	— .020	— .149
1 — 2		— 4.206	— .009	— 9.136	+ .200	— 2.474	— 6.095
2 — 2		+ 19.907	+ .549	+ 45.566	+ 1.270	+ .095	— .067
3 — 2		+ 1.056	— .086	+ 1.642	— .441	— .922	+ 2.011
4 — 2		+ .027	+ .033	— .115	+ .180	— .064	+ .194
0 — 3		+ .05390	— .01764	+ .0718	— .0602	— .030	+ .017
1 — 3		— .33396	— .07957	— .4443	— .3306	— .045	— .166
2 — 3		+ .39221	+ .03380	— 2.1788	+ .1339	— 1.424	— 3.658
3 — 3		+ 8.338	+ .340	+ 27.227	+ 1.087	— .064	— .134
4 — 3		+ .675	— .036	+ 1.796	— .269	— .519	+ 1.099
5 — 3		+ .028	+ .016	+ .043	+ .157	— .042	+ .123
2 — 4		+ .027	— .043	— .054	— .210	— .046	— .146
3 — 4		+ .275	+ .023	— .880	+ .908	— .784	— 2.078
4 — 4		+ 3.628	+ .197	+ 15.430	+ .882	— .038	— .106
5 — 4		+ .397	— .013	+ .883	— .137	— .282	+ .586
6 — 4		+ .021	+ .008	— .013	+ .063	— .031	+ .083
3 — 5		+ .020	— .023	— .034	— .078	+ .020	— .130
4 — 5		+ .167	+ .012	— .281	+ .044	— .411	— 1.150
5 — 5		+ 1.623	+ .109	+ 8.605	+ .543	+ .024	— .227
6 — 5		+ .224	— .004	+ 1.061	+ .064	— .158	+ .311
4 — 6		+ 0.012	— .008	— 0.075	— 0.095		
5 — 6		+ .092	+ .007	— 2.225	+ .026		
6 — 6		+ .731	+ .059	+ 4.559	+ .386		

Having $a\Omega$ we differentiate relative to g , and obtain $a \frac{d\Omega}{dg}$.

We then form the three products, $A \cdot a \frac{d\Omega}{dg}$, $B \cdot ar \left(\frac{d\Omega}{dr} \right)$, $C \cdot a^2 \left(\frac{d\Omega}{dz} \right)$. To this end we find A , B , C , from

$$\begin{aligned} A = & -3 + 2 [2 + e^2] \cos (\gamma - g) & B = & -2 [1 - \frac{e^2}{2}] \sin (\gamma - g) \\ & + 2 [\frac{e}{2} + \frac{e^3}{8}] \cos (\gamma - 2g) & & - 2 [\frac{e}{2} + \frac{e^3}{8}] \sin (\gamma - 2g) \\ & - 2 [5\frac{e}{2} + \frac{25e^3}{16}] \cos \gamma & & - 2 [\frac{e}{2} + \frac{7e^3}{16}] \sin \gamma \\ & + 2 \frac{e^2}{4} \cos (\gamma - 3g) & & - 2 \frac{3}{8} e^2 \sin (\gamma - 3g) \\ & + 2 \frac{e^3}{6} \cos (\gamma - 4g) & & - 2 \frac{e^3}{3} \sin (\gamma - 4g) \\ & + \text{etc.} & & - \text{etc.} \end{aligned}$$

$$\begin{aligned} C = & 2 [\frac{1}{2} - \frac{1}{4}e^2] \sin (\gamma - g) \\ & + 2 [\frac{e}{4} - \frac{3}{16}e^3] \sin (\gamma - 2g) \\ & + 2 [-\frac{3}{4}e + \frac{3}{32}e^3] \sin \gamma \\ & + 2 \frac{3}{16}e^2 \sin (\gamma - 3g) \\ & + 2 \frac{1}{6}e^3 \sin (\gamma - 4g) \\ & + \text{etc.} \end{aligned}$$

The numerical values of A , B , C in case of Althæa are

$$\begin{aligned} A = & -3 \\ & + 2 [0.302429] \cos (\gamma - g) & B = & -2 [0.001399] \sin (\gamma - g) \\ & + 2 [8.604489] \cos (\gamma - 2g) & & - 2 [8.604489] \sin (\gamma - 2g) \\ & - 2 [9.304508] \cos \gamma & & - 2 [8.606234] \sin \gamma \\ & + 2 [7.2076] \cos (\gamma - 3g) & & - 2 [7.3836] \sin (\gamma - 3g) \\ \\ C = & + 2 [9.697567] \sin (\gamma - g) \\ & + 2 [8.30066] \sin (\gamma - 2g) \\ & - 2 [8.77953] \sin \gamma \\ & + 2 [7.08265] \sin (\gamma - 3g) \end{aligned}$$

For the three products we then have

$$A \cdot a \left(\frac{d\Omega}{d\bar{g}} \right)$$

$$B \cdot ar \left(\frac{d\Omega}{dr} \right)$$

$$C \cdot a^2 \left(\frac{d\Omega}{dz} \right)$$

γ	g	g'	sin	cos	sin	cos	sin	cos
			"	"	"	"	"	"
1	0	0	+ 2.1035	—0.5371	+ 1.1341	—0.6804	—1.3464	—3.0038
1	1	0	— .012	+ .565	+ .4021	+ .3723	+ .1287	+ .2411
—1	1	—0	— .2530	+ .0439	—32.9502	+ .0549	— .3877	— .4802
1	2	0	— .192	+ .299	— .0153	+ .1657	— .0049	+ .0228
—1	2	—0	+ 2.079	— .597	— 1.1310	+ .6821	+ 1.2995	+ 2.9772
—1	3	—0	+ .261	+ .457	— .1263	— .3720	+ .083	+ .2404
1	—2	—1	+ .462	+ .181	+ .432	— .348	— .076	+ .243
1	—1	—1	— .266	— .015	+ .453	+ .461	—1.881	+ 4.454
1	0	—1	—10.992	+ .153	—18.335	+ .187	+ .354	— .642
—1	0	—1	+ .462	+ .181	— .477	+ .349	— .228	+ .572
1	1	—1	+ 3.680	— .815	+ .929	— .559	— .815	—1.785
—1	1	—1	+ 1.119	— .013	— .449	— .476	+ 1.906	—4.470
1	2	—1	— .342	+ .477	+ .306	+ .276	+ .067	+ .098
—1	2	—1	—11.301	+ .249	+ 18.336	— .188	— .178	— .359
—1	3	—1	+ 2.360	— .843	— .929	+ .559	+ .785	+ 1.760
—1	4	—1	— .033	+ .381	— .264	— .276		
1	—1	—2	+ .232	.000	— .232		— .060	+ .194
1	0	—2	+ 6.837	+ .026	+ 7.300	+ .235	—1.230	+ 3.029
—1	0	—2	....	....			— .001	+ .009
1	1	—2	—80.684	+ 2.195	—45.412	+ 1.264	+ .178	— .371
—1	1	—2	— .848	+ .002	+ .132	+ .406	— .139	+ .290
1	2	—2	+ 1.633	— .735	— 3.470	— .384	— .467	—1.010
—1	2	—2	+ 16.433	— .240	— 7.317	— .235	+ 1.239	—3.036
1	3	—2	+ .422	+ .316	+ .048	+ .168	+ .024	+ .023
—1	3	—2	—79.078	+ 2.254	+ 45.412	—1.264	— .053	— .273
—1	4	—2	— 7.937	— .500	— .213	+ .384	+ .454	+ .981
—1	5	—2	— .408	+ .255	+ .198	— .163		
1	0	—3	+ .5985	— .1553	+ .4644	— .3261	— .0482	+ .157
1	1	—3	— 2.6517	+ .1927	+ 1.1042	+ .1641	— .7083	+ 1.8160
—1	1	—3	— .0661	+ .0161	+ .0541	+ .0737	+ .0123	+ .0180
1	2	—3	—50.140	+ 1.905	—27.2994	+ 1.0854	+ .043	+ .174
—1	2	—3	+ .828	— .1733	— .5308	+ .3287	— .062	+ .136
1	3	—3	— .380	— .492	— 2.8964	— .2201	— .256	— .558
—1	3	—3	+ 3.482	— .073	— 1.1112	— .1645	+ .707	—1.818
1	4	—3	+ .263	+ .190	— .115	+ .147	+ .010	+ .005
—1	4	—3	—49.676	+ 2.079	+ 27.299	—1.083	+ .029	— .206
—1	5	—3	— 6.395	— .264	+ 3.899	+ .217	+ .257	+ .534

$$A \cdot a \left(\frac{d\Omega}{dg} \right)$$

$$B \cdot ar \left(\frac{d\Omega}{dr} \right)$$

$$C \cdot a^2 \left(\frac{d\Omega}{dz} \right)$$

γ	g	g'	sin	cos	sin	cos	sin	cos
			"	"	"	"	"	"
1	1	— 4	— .165	— .170	....		— .038	+ .115
1	2	— 4	— 2.229	+ .187	+ .264	+ .939	— .389	+1.029
—1	2	— 4	+ .011	+ .017	....		+ .008	+ .014
1	3	— 4	—29.032	+1.564	—15.481	+ .915	+ .022	— .083
—1	3	— 4	+ .058	— .187	— .089	+ .175	— .024	+ .051
1	4	— 4	— 1.063	— .287	— 1.504	— .098	— .140	— .300
—1	4	— 4	+ 1.268	— .024	— .022	— .938	+ .390	—1.033
—1	5	— 4	—28.751	+1.597	+15.479	— .915	+ .033	— .129
—1	6	— 4	— 4.543	— .108	+ 1.506	+ .098		
1	2	— 5	— .160	— .136			+ .002	+ .088
1	3	— 5	— 1.654	+ .132	— .063	+ .063	— .206	+ .570
—1	3	— 5	+ .012	+ .014	— .001	— .003	+ .001	+ .008
1	4	— 5	—16.185	+1.082	— 8.661	+ .544	— .034	+ .038
—1	4	— 5	+ .015	— .148	— .045	+ .076	— .035	+ .004
1	5	— 5	— 1.061	— .158	— 1.412	— .036	— .080	— .168
—1	5	— 5	+ .294	— .017	+ .062	— .063	+ .206	— .563
—1	6	— 5	—16.038	+1.100	+ 8.661	— .544		
1	3	— 6	— .121	— .063				
1	4	— 6	— 1.088	+ .086	+ 2.052	+ .038		
1	5	— 6	— 8.707	+ .703	— 4.516	+ .387		
—1	7	— 6	— 8.818	+ .711	+ 4.516	— .387		

Next from

$$\frac{dW}{ndt} = A \cdot a \left(\frac{d\Omega}{dg} \right) + B \cdot ar \left(\frac{d\Omega}{dr} \right)$$

we find the value of $\frac{dW}{ndt}$. Then we find W and $\frac{u}{\cos i}$ from

$$W = \int \frac{dW}{ndt}$$

$$\frac{u}{\cos i} = \int C \cdot a^2 \left(\frac{d\Omega}{dz} \right).$$

We first form a table giving the integrating factors. From $\log. n' = 2.4758576$, $\log. n = 2.9323542$, we have $\frac{n'}{n} = 0.34954524$.

i	i'	$i + i' \frac{n'}{n}$	$\text{Log.} \left(i + i' \frac{n'}{n} \right)$	$\text{Log.} \left(\frac{1}{i + i' \frac{n'}{n}} \right)$	i	i'	$i + i' \frac{n'}{n}$	$\text{Log.} \left(i + i' \frac{n'}{n} \right)$	$\text{Log.} \left(\frac{1}{i + i' \frac{n'}{n}} \right)$
-2	-1	-2.34954	0.37098 <i>n</i>	9.62902 <i>n</i>	3	-3	+1.95136	0.29034	9.70966
-1	-1	-1.34954	0.13018 <i>n</i>	9.86982 <i>n</i>	4	-3	+2.95136	0.47002	9.52998
0	-1	-.34954	9.54350 <i>n</i>	0.45650 <i>n</i>	5	-3	+3.95136	0.5968	9.4032
1	-1	+.65045	9.813217	0.186783	1	-4	-.398181	9.60008 <i>n</i>	0.39992 <i>n</i>
2	-1	+1.65045	0.21760	9.78240	2	-4	+.601819	9.77946	0.22054
3	-1	+2.65045	0.4233	9.5767	3	-4	+1.601819	0.20461	9.79539
4	-1	+3.65045	0.5624	9.4376	4	-4	+2.601819	0.41528	9.58472
-1	-2	-1.69909	0.23021 <i>n</i>	9.76979 <i>n</i>	5	-4	+3.601819	0.5565	9.4435
0	-2	-.69909	9.8446 <i>n</i>	0.1554 <i>n</i>	6	-4	+4.601819	0.6630	9.3370
1	-2	+.30091	9.478423	0.521577	2	-5	+.252274	9.40187	0.59813
2	-2	+1.30091	0.11425	9.88575	3	-5	+1.252274	0.09770	9.90230
3	-2	+2.30091	0.36190	9.63810	4	-5	+2.252274	0.35263	9.64737
4	-2	+3.30091	0.5186	9.4814	5	-5	+3.252274	0.5122	9.4878
5	-2	+4.30091	0.6336	9.3664	6	-5	+4.252274	0.6286	9.3714
0	-3	-1.04864	0.02062 <i>n</i>	9.97938 <i>n</i>	3	-6	+.902729	9.9556	0.0444
1	-3	-.04863572	8.6869553 <i>n</i>	1.3130447 <i>n</i>	4	-6	+1.902729	0.2794	9.7206
2	-3	+.95136	9.97835	0.02165	5	-6	+2.902729	0.4628	9.5372

In regard to this table we may add that the form of the angles is $(ig + i'g') = (i + i' \frac{g'}{g})g = (i + i' \frac{n'}{n})nt$. The differential relative to the time is $(i + i' \frac{n'}{n})ndt$.

The preceding table is applied by subtracting the logarithms of the column headed $\log. (i + i' \frac{n'}{n})$, or by adding the logarithms of the column headed $\log. (\frac{1}{i + i' \frac{n'}{n}})$.

We will now give the values of $\frac{dW}{ndt}$, W , and $\frac{u}{\cos i}$, remarking that in the integrations the angle γ is constant; after the integrations it changes into g .

			$\frac{dW}{ndt}$		W		$\frac{u}{\cos i}$	
γ	g	g'	sin	cos	cos	sin	cos	sin
			"	"	"	"	"	"
1	0	0	+ 3.2376	— 1.2175	— 1.2175 <i>nt</i>	+ 3.2376 <i>nt</i>	— 3.0038 <i>nt</i>	— 1.3464 <i>nt</i>
1	1	0	+ .3901	+ .9373	— .3901	+ .9373	— .1287	+ .2411
1	1	0	+ 32.6972	+ .0988	— 32.6972	+ .0988	+ .3877	— .4802
1	2	0	— .2073	+ .4647	+ .1036	.2323	+ .0024	+ .0114
—1	2	0	+ .9480	+ .0851	— .4740	+ .0425	— .6497	+ 1.4886
1	3	0	+ .1350	+ .0850	— .0450	+ .0283	— .028	+ .0801
1	— 2	— 1	+ .894	— .167	+ .383	+ .07	— .033	— .10
1	— 1	— 1	+ .187	+ .446	+ .115	+ .330	— 0.62	— 1.60
1	0	— 1	— 29.327	+ .340	— 83.900	— .973	+ 1.013	+ 1.84
—1	0	— 1	— .015	+ .530	— .045	— 1.516	— .652	— 1.64
1	1	— 1	+ 4.609	— 1.374	— 7.087	— 2.112	+ 1.264	— 2.74
—1	1	— 1	+ .670	— .489	— 1.030	— .752	— 1.370	— 3.21
1	2	— 1	— .036	+ .753	+ .022	+ .456	— .040	+ .06
—1	2	— 1	+ 7.035	+ .061	— 4.263	+ .038	+ .107	— .21
1	3	— 1	— .019	+ .254	+ .007	+ .096		
—1	3	— 1	+ 1.431	— .284	— .540	— .107	— .296	+ .670
—1	4	— 1	— .297	+ .105	+ .081	+ .029		
1	— 1	— 2					— .03	— .11
1	0	— 2	+ 14.145	+ .261	+ 20.207	— .373	— 1.76	— 4.33
1	1	— 2	— 126.276	+ 3.459	+ 419.660	+ 11.503	— .59	— 1.23
1	1	— 2	— .716	+ .408	+ 2.380	+ 1.356	+ .46	+ .96
1	2	— 2	— 1.837	— 1.119	+ 1.410	— .860	+ .36	— .78
—1	2	— 2	+ 9.116	— .475	— 7.008	— .365	— .95	— 2.34
1	3	— 2	+ .470	+ .484	— .204	+ .210	— .01	+ .01
1	3	— 2	— 33.666	+ .990	+ 14.632	+ .430	+ .02	— .12
1	4	— 2	— .017	+ .125	+ .005	+ .038		
—1	4	— 2	— 8.150	— .116	+ 2.469	— .035	— .14	+ .30
1	5	— 2	— .210	+ .092	+ .050	+ .021		
1	0	— 3	+ 1.0629	— .4814	+ 1.0136	+ .4591	— .05	— .15
1	1	— 3	— 1.5475	+ .3568	— 31.8180	— 7.335	— 14.56	— 37.33
—1	1	— 3	— .0120	+ .0898	— .2452	— 1.847	+ .25	— .37
1	2	— 3	— 77.4394	+ 2.9904	+ 81.400	+ 3.139	— .04	— .18
—1	2	— 3	+ .2972	+ .1554	— .3124	+ .1631	+ .06	+ .14
1	3	— 3	— 3.2764	— .7121	+ 1.679	— .365	+ .13	— .28
—1	3	— 3	+ 2.3706	— .2375	— 1.216	— .122	— .36	— .91
1	4	— 3	+ .148	+ .337	— .050	+ .115	.00	.00
—1	4	— 3	— 22.377	+ .996	+ 7.413	+ .338	— .01	— .07
—1	5	— 3	— 2.496	— .047	+ .627	— .012	— .06	+ .13
1	1	— 4	— .165		— .414		— .096	— .29
1	2	— 4	— 1.965 ^{1/2}	+ 1.126	+ 3.265	+ 1.871	+ .647	+ 1.71
1	3	— 4	— 44.513 ^{1/2}	+ 2.479	+ 27.790	+ 1.548	— .014	— .05
—1	3	— 4	— .031	— .012	+ .019	— .007	+ .015	+ .03
1	4	— 4	— 2.567	— .385	+ .986	— .148	+ .054	— .12
—1	4	— 4	+ 1.002	— .963	— .385	— .370	— .150	— .40
1	5	— 4	— .022	+ .057	+ .006	+ .016		
—1	5	— 4	— 13.272	+ .682	+ 3.686	+ .190	— .009	— .04
—1	6	— 4	— 3.037	— .010	+ .660	— .002		

			$\frac{dW}{ndt}$		W		$\frac{u}{\cos i}$	
γ	g	g'	sin	cos	cos	sin	cos	sin
			"	"	"	"	"	"
1	3	— 5	— 1.717	+ .195	+ 1.374	+ .156	+ .163	+ .46
—1	3	— 5	+ .011	+ .017	— .009	+ .014	— .001	+ .01
1	4	— 5	— 24.846	+ 1.626	+ 11.030	+ .722	— .015	+ .02
—1	4	— 5	— .030	— .072	+ .013	— .032	+ .016	.00
1	5	— 5	— 2.473	— .194	+ .760	— .060	+ .025	— .05
—1	5	— 5	+ .356	— .080	— .110	— .024	— .064	— .18
1	6	— 5	— .089	+ .160	+ .021	+ .038		
—1	6	— 5	— 7.377	+ .556	+ 1.735	+ .130		
—1	7	— 5	+ 1.413	+ .036	— .270	+ .007		
1	4	— 6	+ .964	+ .124	— .507	+ .07		
1	5	— 6	— 13.223	+ 1.090	+ 4.555	+ .38		
—1	5	— 6	— .167	+ .023	+ .057	+ .06		
1	6	— 6	— .946	— .002	+ .242	.00		
—1	6	— 6	— 2.098	— .040	+ .538	— .01		
—1	7	— 6	— 3.302	+ .324	+ .674	+ .09		

The part of W independent of γ arising from the factor, -3 , in the value of A , has not yet been given. Its integral, or $\int -3a \left(\frac{d\Omega}{dg} \right)$, is the following:

$$\int -3a \left(\frac{d\Omega}{dg} \right)$$

g	g'	cos	sin	g	g'	cos	sin
		"	"			"	"
1	— 0	+ 3.1392	+ .8181	4	— 3	— 2.74	+ .14
2	— 0	+ .1509	— .3757	5	— 3	— .11	— .06
3	— 0	— .0858	— .1738				
				2	— 4	— .27	+ .43
—1	— 1	— .51	+ .20	3	— 4	— 1.54	— .13
1	— 1	— 25.39	— .39	4	— 4	— 16.74	— .91
2	— 1	+ 2.33	+ .73	5	— 4	— 1.65	+ .05
3	— 1	— .04	— .22	6	— 4	— .08	— .03
1	— 2	+ 41.934	+ .090	3	— 5	— .14	+ .16
2	— 2	— 91.80	— 2.53	4	— 5	— .89	— .06
3	— 2	— 4.13	+ .34	5	— 5	— 7.49	— .50
4	— 2	— .10	— .12	6	— 5	— .95	+ .02
1	— 3	— 20.6020	— 4.9099	4	— 6	— .07	+ .05
2	— 3	— 2.473	— .210	5	— 6	— .48	— .04
3	— 3	— 38.46	— 1.57	6	— 6	— 3.35	— .27

Having the values of the coefficients of $(\pm \gamma + ig + i'g')$, both for W and $\frac{u}{\cos i}$, we have next to find those of $(\pm \nu \gamma + ig + i'g')$, and of $(0\gamma + ig + i'g)$ in the case of $\frac{u}{\cos i}$.

The expressions for this purpose are

$$\eta^{(2)} = \frac{1}{2}e - \frac{1}{8}e^3 - \frac{1}{384}e^5$$

$$\eta^{(3)} = \frac{3}{8}e^2 - \frac{15}{128}e^4$$

$$\eta^{(4)} = \frac{1}{8}e^3$$

$$\eta^{(0)} = -(\frac{3}{2}e + \frac{9}{16}e^3 \pm \text{etc.})$$

For Althæa we find

$$\log. \eta^{(2)} = 8.60309 \quad \log. \eta^{(3)} = 7.38368 \quad \log. \eta^{(0)} = 9.08196n$$

We multiply the coefficients of $(\pm \gamma + ig + i'g')$ by $\eta^{(2)}$, and $\eta^{(3)}$, respectively, to find those of $(\pm 2\gamma + ig + i'g')$, $(\pm 3\gamma + ig + i'g')$.

In case of $(0\gamma + ig + i'g')$ in the expression for $\frac{u}{\cos i}$ we add the coefficients of $(+\gamma + ig + i'g')$ to those of $(-\gamma + ig + i'g)$ and multiply the sum by $\eta^{(0)}$.

We will give a few examples to show the formation of \bar{W} , and $-\frac{1}{2}\frac{d\bar{W}}{d\gamma}$.

With these two we give at once also their integrals, which are $n\delta z$ and ν respectively.

		\bar{W}		$-\frac{1}{2}\frac{d\bar{W}}{d\gamma}$	
		(0 — 0)			
		cos	sin	sin	cos
		"	"	"	"
-- 1	1 — 0	—32.6972	+ .0988	+16.3486	+ .0494
— 2	2 — 0	— .0190	+ .0017	+ .0190	+ .0017
		—32.7162			+ .0511
		"			"
		—32.7162 <i>nt</i>			+ .0511 <i>nt</i>

W				$-\frac{1}{2}\frac{d\overline{W}}{d\gamma}$	
(1 — 0)					
		"	"	"	"
— 1	2 — 0	— .474	+ .042	+ .237	+ .021
0	1 — 0	+3.139	+ .818	—	—
2	1 — 0	—1.314	— .004	—1.314	+ .004
1	0 — 0	—1.2175 <i>nt</i>	+3.2376 <i>nt</i>	— .6087 <i>nt</i>	—1.6188 <i>nt</i>
		"	"	"	"
		+1.351	—1.2175 <i>nt</i>	+ .856	+3.2376 <i>nt</i>
		"	"	"	"
		+4.59	—1.2175 <i>nt</i>	—2.07	—3.2376 <i>nt</i>
		"	"	"	"
		—1.077	— .6087 <i>nt</i>	+ .025	—1.6188 <i>nt</i>
		"	"	"	"
		—0.54	+ .6087 <i>nt</i>	—0.58	—1.6188 <i>nt</i>
(— 1 — 1)					
		"	"	"	"
1	2 — 1	+ .383	+ .070	+ .191	— .035
— 1	0 — 1	— .045	—1.516	+ .022	— .758
— 2	1 — 1	— .041	— .030	+ .041	— .030
0	1 — 1	— .513	+ .200	—	—
		—0.216	—1.246	+ .254	— .823
		"	"	"	"
		+ .16	— .92	+ .19	+ .61
(1 — 1)					
		"	"	"	"
— 2	3 — 1	— .022	— .004	+ .022	— .004
— 1	2 — 1	— 4.263	+ .038	+ 2.131	+ .019
0	1 — 1	— 25.390	— .390	—	—
1	0 — 1	— 83.900	— .973	—41.950	+ .486
		—113.574	—1.329	—39.798	+ .501
		"	"	"	"
		—174.61	+2.04	+61.19	+0.77

In the integration we apply the proper factor to each term of \bar{W} , $-\frac{1}{2} \frac{d\bar{W}}{d\gamma}$, and obtain the values of $n\delta z$, v , except in case of the terms ($ig + og'$).

Let us take the term ($g - og'$) or (1 — 0), and let μ the integrating factor to be applied.

Let c , a , d , b , represent the \cos , \sin , $nt \cos$, $nt \sin$ terms respectively.

Thus we have

$$\begin{array}{cccc} c & d & a & b \\ '' & '' & '' & '' \\ +1.351 & -1.2175nt & +.856 & +3.2376nt; \end{array}$$

and hence

$$\begin{array}{cccccc} \mu c & \mu^2 b & \mu d & -\mu a & \mu^2 d & -\mu b \\ '' & '' & '' & '' & '' & '' \\ +1.351 & +3.2376 & -1.2175nt & -.856 & -1.2175 & -3.2376nt \end{array}$$

or, since μ is unity,

$$\begin{array}{cccc} '' & '' & '' & '' \\ +4.59 & -1.2175nt & -2.07 & -3.2376. \end{array}$$

In case of the term $(2 - 0)$, μ is $\frac{1}{2}$.

In the way indicated we derive the values of $n\delta z$, and ν . In the case of $\frac{u}{\cos i}$ we have the values at once without another integration as was necessary for $n\delta z$ and ν .

In the value of W given above the arbitrary constants of integration have not been applied.

We give these constants in the form

$$k_0 + k_1 \cos \gamma + k_2 \sin \gamma + \eta^{(2)} k_1 \cos 2\gamma + \eta^{(2)} k_2 \sin 2\gamma + \text{etc.}$$

Then in case of $-\frac{1}{2} \frac{dW}{d\gamma}$ we have

$$\frac{1}{2} k_1 \sin \gamma - \frac{1}{2} k_2 \cos \gamma + \eta^{(2)} k_1 \sin 2\gamma - \eta^{(2)} k_2 \cos 2\gamma \pm \text{etc.}$$

Having W from the integration of $\frac{dW}{n\delta t}$, we form \bar{W} from the value of W and converting γ into g .

We thus have from the equation

$$\begin{aligned} \frac{dz}{dt} &= 1 + W + \frac{h_0}{h} \left(\frac{\nu}{1 + \nu} \right)^2, \\ \frac{dz}{dt} &= 1 + k_0 \\ &+ (1''.351 + k_1) \cos g && + (0''.856 + k_2) \sin g \\ &- 1''.2175nt \cos g && + 3''.2376nt \sin g \\ &+ (-''.284 + \eta^{(2)} k_1) \cos 2g && + (0''.589 + \eta^{(2)} k_2) \sin 2g \\ &- ''.0488nt \cos 2g && + ''.1298nt \sin 2g \\ &\pm \text{etc.} && \pm \text{etc.} \end{aligned}$$

In the second integration the constants of $n\delta z$ and ν are designated by C and N respectively, and the complete forms are

$$\begin{aligned} C + k_0 nt + k_1 \sin g - k_2 \cos g + \frac{1}{2}\eta^{(2)} k_1 \sin 2g - \frac{1}{2}\eta^{(2)} k_2 \cos 2g \pm \text{etc.} \\ N - \frac{1}{2}k_1 \cos g - \frac{1}{2}k_2 \sin g - \frac{1}{2}\eta^{(2)} k_1 \cos 2g - \frac{1}{2}\eta^{(2)} k_2 \sin 2g - \text{etc.} \end{aligned}$$

In case of the latitude the constants of integration have the form

$$l_0 + l_1 \sin g + l_2 \cos g.$$

We thus find

$$\begin{aligned} nz = C + [1 + k_0 - 32''.7162]nt \\ + [4''.59 + k_1] \sin g + [-2''.07 - k_2] \cos g \\ - 1''.2175nt \sin g - 3''.2376nt \cos g \\ + [-0''.11 + \frac{1}{2}\eta^{(2)} k_1] \sin 2g + [-0''.31 - \frac{1}{2}\eta^{(2)} k_2] \cos 2g \\ - 0''.0244nt \sin 2g - 0''.0649nt \cos 2g \\ \pm \text{etc.} \quad \pm \text{etc.} \end{aligned}$$

$$\begin{aligned} \nu = + 0''.0511nt + N \\ + [-0''.54 - \frac{1}{2}k_1] \cos g + [-0''.58 - \frac{1}{2}k_2] \sin g \\ + 0''.6087nt \cos g - 1''.6188nt \sin g \\ + [0''.05 - \frac{1}{2}\eta^{(2)} k_1] \cos 2g + [-''.24 - \frac{1}{2}\eta^{(2)} k_2] \sin 2g \\ + 0''.0244nt \cos 2g - 0''.0649nt \sin 2g \\ \pm \text{etc.} \quad \pm \text{etc.} \end{aligned}$$

$$\begin{aligned} \frac{u}{\cos i} = l_0 + 0''.3616 + 0''.3623nt \\ + [1''.52 + l_1] \sin g + [-0''.68 + l_2] \cos g \\ - 1''.3464nt \sin g - 3''.0038nt \cos g \\ + 0''.32 \sin 2g - 0''.16 \cos 2g \\ - 0''.0539nt \sin 2g - 0''.1204nt \cos 2g \\ \pm \text{etc.} \quad \pm \text{etc.} \end{aligned}$$

The complete expressions for $n\delta z$, ν , $\frac{u}{\cos i}$ in tabular form are the following:

g	g'	$n\delta z$		ν		$\frac{u}{\cos i}$	
		sin	cos	cos	sin	sin	cos
0	0		$+k_0 nt$	$+N$		$+l_0$	$+0.36$
			$-32.7162nt$	$+ .0511nt$			$+ .3623nt$
1	0	$-4.59 + k_1$	$-2.07 - k_2$	$-0.54 - \frac{1}{2}k_1$	$-.58 - \frac{1}{2}k_2$	$+1.52 + l_1$	$-.68 + l_2$
		$-1.2175nt$	$-3.2376nt$	$+0.6087nt$	$-1.6188nt$	$-1.3464nt$	$-3.0038nt$
2	0	$-0.11 + \frac{1}{2}\eta^{(2)}k_1$	$-.31 - \frac{1}{2}\eta^{(2)}k_2$	$+ .05 - \frac{1}{2}\eta^{(2)}k_1$	$-.24 - \frac{1}{2}\eta^{(2)}k_2$	$+ .32$	$-.16$
		$-0.0244nt$	$-.0649nt$	$+ .0244nt$	$-.0649nt$	$- .0539nt$	$-.1204nt$
0	1	$+3.10$	-3.09	$+2.12$	-1.54	-4.83	-2.03
0	2	-3.00	$+1.92$	-1.30	$-.95$	$+1.30$	$+ .61$
0	3	$+0.23$	-1.76	$+ .12$	$+ .89$	$-.37$	$+ .25$
1	1	-174.61	$+2.04$	$+61.19$	$+ .77$	$+2.69$	$+1.26$
2	2	$+263.97$	-7.21	-156.21	-4.24	-1.15	$-.57$
3	3	$+25.15$	-0.81	-18.30	$-.56$	-1.60	$-.60$
4	4	$+5.71$	-0.35	-4.68	$-.29$	$+ .03$	$+ .02$
5	5	$+1.64$	-0.11	-1.45	$-.09$		
6	6	$+ .49$	$-.05$	$-.50$	$-.04$		
1	2	$+185.18$	$+2.10$	-43.27	$+ .07$	-6.64	-2.70
2	4	-1.10	$-.71$	$+ .36$	$-.01$	$-.47$	$-.17$
1	3	$+410.16$	-87.44	$+14.64$	$+3.15$	$+4.43$	$+1.73$
2	1	-5.25	$+ .87$	$+4.02$	$+ .62$	-1.98	$+ .99$
2	3	-37.24	$+8.03$	$+16.07$	$+3.78$	-38.24	-14.92
3	2	$+6.77$	$+ .04$	-7.08	$-.01$	$-.52$	$+ .20$
3	4	$+ .90$	$-.86$	1.05	$-.70$	$+1.31$	$+ .50$
4	3	$+ .92$	$+ .04$	$-.69$	$+ .05$	$-.24$	$+ .03$
4	5	$+ .17$	$-.03$	$-.33$	$-.04$	$+ .28$	$+ .10$
5	4	$+ .34$	$+ .01$	$-.38$	$.00$		
-1	1	$+ .16$	$-.92$	$+ .19$	$+ .61$	-1.62	$-.63$

The constants of integration are now to be so determined as to make the perturbations zero for the Epoch. The following equations fulfill this condition :

$$\begin{aligned}
 C + k_1 \sin g - k_2 \cos g + \frac{1}{2}\eta^{(2)} k_1 \sin 2g - \frac{1}{2}\eta^{(2)} k_2 \cos 2g \pm \text{etc.} + (n\delta z)_0 &= g_0 \\
 k_0 + k_1 \cos g + k_2 \sin g + \eta^{(2)} k_1 \cos 2g + \eta^{(2)} k_2 \sin 2g + \text{etc.} + \frac{d}{ndt} (n\delta z)_0 &= 0 \\
 N - \frac{1}{2}k_1 \cos g - \frac{1}{2}k_2 \sin g - \frac{1}{2}\eta^{(2)} k_1 \cos 2g - \frac{1}{2}\eta^{(2)} k_2 \sin 2g - \text{etc.} + (\nu)_0 &= 0 \\
 + \frac{1}{2}k_1 \sin g - \frac{1}{2}k_2 \cos g + \eta^{(2)} k_1 \sin 2g - \eta^{(2)} k_2 \cos 2g \pm \text{etc.} + \frac{d}{ndt} (\nu)_0 &= 0 \\
 l_0 + l_1 \sin g + l_2 \cos g + \eta^{(2)} l_1 \sin 2g + \eta^{(2)} l_2 \cos 2g + \text{etc.} + \left(\frac{u}{\cos i}\right)_0 &= 0 \\
 l_1 \cos g - l_2 \sin g + \eta^{(2)} l_1 \cos 2g - \eta^{(2)} l_2 \sin 2g \pm \text{etc.} + \frac{d}{ndt} \left(\frac{u}{\cos i}\right)_0 &= 0
 \end{aligned}$$

To find k_1 and k_2 we have

$$\begin{aligned}
 k_1 [\cos g - e + \eta^{(2)} \cos 2g + \eta^{(3)} \cos 3g + \text{etc.}] + k_2 [\sin g + \eta^{(2)} \sin 2g + \text{etc.}] \\
 - 3Z_0 + 6(\nu)_0 + 4\frac{d}{ndt} (n\delta z)_0 &= 0 \\
 k_1 [\sin g + 2\eta^{(2)} \sin 2g + 3\eta^{(3)} \sin 3g + \text{etc.}] - k_2 [\cos g + 2\eta^{(2)} \cos 2g + \text{etc.}] \\
 + 2\frac{d}{ndt} (\nu)_0 &= 0
 \end{aligned}$$

where

$$N = -\frac{2}{3}k_0 - \frac{e}{6}k_1 - \frac{1}{2}Z_0, \quad Z_0 = -32''.7162,$$

k_0 being found from

$$k_0 = ek_1 + 3Z_0 - 3\frac{d}{ndt} (n\delta z)_0 - 6(\nu)_0.$$

We have also

$$l_0 = -el_2.$$

The symbols $(n\delta z)_0$, $(\nu)_0$, etc., represent the values of $n\delta z$, ν , etc., at the Epoch.

To find the values of the angles $(ig + i'g)$ at the Epoch we have

$$g = 332^\circ 48' 53''.2$$

$$g' = 63 \quad 5 \quad 48 \quad .6$$

The long period inequality, 5 Saturn — 2 Jupiter, is included in the value of g' .

From these values of g and g' we find the various arguments of the perturbations. Then forming the sine and cosine for each argument, we multiply the sine and cosine coefficients of the perturbations by their appropriate sines and cosines.

In forming $\frac{d}{ndt}(n\delta z)$, etc., we can make use of the integrating factors, multiplying by the numbers in the column $(i + i' \frac{n'}{n})$. Having their differential coefficients we proceed as in the case of $(n\delta z)$, etc.

We thus find

$$(n\delta z)_0 = +401''.7, \quad (\nu)_0 = +180''.6, \quad \left(\frac{u}{\cos i}\right) = -22''.6$$

$$\frac{d}{ndt}(n\delta z)_0 = -391''.6, \quad \frac{d}{ndt}(\nu)_0 = +70''.5, \quad \frac{d}{ndt}\left(\frac{u}{\cos i}\right) = +41''.5.$$

And from these we have

$$k_1 = +412''.8, \quad k_2 = -82''.9, \quad k_0 = -26''.21, \quad l_0 = 0''.0$$

$$l_1 = -45''.2, \quad l_2 = +0''.4, \quad N = +28''.3,$$

$$C = 332^\circ 44' 12''.6.$$

The new mean motion is found from $(1 - 32''.7162 - 26''.21)nt$, which gives $n = 855''.5196$. With this value of n we find the only change is in the coefficients of the argument $(1 - 3)$, having $+405''.29$ instead of $410''.16$, and $-86''.30$ instead of $-87''.44$.

The constant C now has the value

$$C = 332^\circ 44' 16''.3.$$

Introducing the values of the constants of integration into the expressions for nz , v , and $\frac{u}{\cos i}$; we have

$$\begin{aligned} nz &= 332^{\circ} 44' 16''.3 & + 855''.5196 t \\ &+ 417''.4 \sin g & + 80''.8 \cos g \\ &- 1''.2175 \sin g & - 3''.2376 \cos g \\ &+ 16''.4 \sin 2g & + 3''.0 \cos 2g \\ &- 0''.0244 nt \sin 2g & - 0''.0649 nt \cos 2g \\ &\pm \text{etc.} & \pm \text{etc.} \end{aligned}$$

$$\begin{aligned} v &= + 28''.3 & + 0''.0511 nt \\ &- 206''.9 \cos g & + 40''.9 \sin g \\ &+ 0''.6087 nt \cos g & - 1''.6188 nt \sin g \\ &- 8''.2 \cos 2g & + 1''.3 \sin 2g \\ &+ 0''.0244 nt \cos 2g & - 0''.0649 nt \sin 2g \\ &\pm \text{etc.} & \pm \text{etc.} \end{aligned}$$

$$\begin{aligned} \frac{u}{\cos i} &= + 0''.4 & + 0''.3623 nt \\ &- 44''.2 \sin g & - 0''.7 \cos g \\ &- 1''.3464 nt \sin g & - 3''.0038 nt \cos g \\ &- 1''.5 \sin 2g & - 0''.2 \cos 2g \\ &- 0''.0539 nt \sin 2g & - 0''.1204 nt \cos 2g \end{aligned}$$

From the expressions of the perturbations that have been given, and the elements used in computing the perturbations, except that we use C in place of g_0 and the new value of the mean motion, we will compute a position of the body for the date 1894, Sept. 19, 10^h 48^m 52^s, for which we have an observed position. From a provisional ephemeris we have an approximate value of the distance; its logarithm is 0.14878.

Reducing the above date to Berlin Mean Time, and applying the aberration time, we have, for the observed date, 1894, Sept. 19, 72800,

$$g = 339^\circ 19' 38''.1, \quad g' = 65^\circ 24'.1.$$

Forming the arguments of the perturbations with these, we find

$$n\delta z = +4' 43''.2, \quad \nu = +3''.6, \quad \frac{u}{\cos i} = -2''.8.$$

To convert ν into radius as unity and in parts of the logarithm of the radius vector we multiply by the modulus whose logarithm is 9.63778, and divide by 206264''.8. Thus we have from $\nu = +3''.6$, the correction, +.000008, to be applied to the logarithm of the radius vector.

In case of $\frac{u}{\cos i} = -2''.8$, we have

$$\delta z' = -2''.8 \times a \cos i = -7''.19.$$

Converting into radius as unity, we have $\delta z' = -.000035$. The coördinate z' is perpendicular to the plane of the orbit. As we will use coördinates referred to the equator we have, to find the changes in x, y, z , due to a variation of z' , which we have designated by $\delta z'$, the following expressions:

$$\delta x = (\sin i \sin \oslash) \delta z'$$

$$\delta y = (-\sin i \cos \oslash \cos \varepsilon - \cos i \sin \varepsilon) \delta z'$$

$$\delta z = (-\sin i \cos \oslash \sin \varepsilon + \cos i \cos \varepsilon) \delta z'$$

where ε is the obliquity of the ecliptic.

For 1894 we find

$$\delta x = (-.0404) \delta z', \quad \delta y = (-.3123) \delta z', \quad \delta z = (+.9491) \delta z'$$

And for the date we have

$$\delta x = +.000001 \quad \delta y = +.000011 \quad \delta z = -.000033$$

With $i = 5^\circ 44' 4''.6$, $\oslash = 203^\circ 51' 51''.5$, $\varepsilon = 23^\circ 27' 10''.8$,

we compute the auxiliary constants for the equator from the formulæ

$$\cotg A = -tg \oslash \cos i, \quad tg E_0 = \frac{tg i}{\cos \oslash},$$

$$\cotg B = \frac{\cos i}{tg \oslash \cos E_0} \cdot \frac{\cos (E_0 + \varepsilon)}{\cos \varepsilon},$$

$$\cotg C = \frac{\cos i}{tg \oslash \cos E_0} \cdot \frac{\sin (E_0 + \varepsilon)}{\sin \varepsilon},$$

$$\sin a = \frac{\cos \oslash}{\sin A}, \quad \sin b = \frac{\sin \oslash \cos \varepsilon}{\sin B}, \quad \sin C = \frac{\sin \oslash \sin \varepsilon}{\sin C}.$$

The values of $\sin a$, $\sin b$, $\sin c$ are always positive, and the angle E_0 is always less than 180° .

As a check we have

$$tg i = \frac{\sin b \sin c \sin (C - B)}{\sin a \cos A}$$

We find

$$A = 293^\circ 45' 29''.3, \quad B = 202^\circ 59' 46''.9, \quad C = 210^\circ 45' 55''.0$$

$$\log \sin a = 9.999645, \quad \log \sin b = 9.977735, \quad \log \sin c = 9.498012$$

Applying $n\delta z = + 4' 43''.2$ to the value of g , we have

$$nz = 339^\circ 24' 21''.5$$

By means of g or $nz = E - e \sin E$ we find

$$E = 337^\circ 39' 23''.4$$

Then from

$$\sqrt{r_1} \sin \frac{1}{2} v = \sqrt{a(1+e)} \sin \frac{1}{2} E$$

$$\sqrt{r_1} \cos \frac{1}{2} v = \sqrt{a(1-e)} \cos \frac{1}{2} E$$

we find

$$v = 335^{\circ} 50' 12''.2, \quad \log r_1 = 0.378246$$

where v is the true anomaly.

Calling u the argument of the latitude we have

$$u = v + \pi - \varpi = 143^{\circ} 52' 41''.8.$$

Hence

$$A + u = 77^{\circ} 38' 11''.1, \quad B + u = 346^{\circ} 52' 28''.7, \quad C + u = 354^{\circ} 38' 36''.8.$$

And from

$$x = r \sin a \sin (A + u)$$

$$y = r \sin b \sin (B + u)$$

$$z = r \sin c \sin (C + u),$$

where

$$\log r = \log r_1 + \delta \log r = \log r_1 + .000008,$$

we have

$$x = + 2.331894, \quad y = - .515433, \quad z = - .070208.$$

The equatorial coördinates of the Sun for the date of the observation are

$$X = - 1.002563 \quad Y = + .045198 \quad Z = + .019611.$$

Applying the corrections $\delta x, \delta y, \delta z$, we have

$$x + \delta x + X = + 1.329332, \quad y + \delta y + Y = - .470224, \quad z + \delta z + Z = - .050630.$$

Then from

$$\begin{aligned} \operatorname{tg} \alpha &= \frac{y + \delta y + Y}{x + \delta x + X}, \quad \operatorname{tg} \delta = \frac{z + \delta z + Z}{y + \delta y + Y} \sin \alpha = \frac{z + \delta z + Z}{x + \delta x + X} \cos \alpha, \\ \Delta &= \frac{z + \delta z + Z}{\sin \delta}, \end{aligned}$$

we have, giving also the observed place for the purpose of comparison,

$$\begin{aligned} \alpha_c &= 340^\circ 31' 11''.4 & \delta_c &= -2^\circ 3' 23''.1 & \log \Delta &= 0.149514. \\ \alpha_o &= 340 \quad 33 \quad 49.1 & \delta_o &= -2 \quad 2 \quad 25.4 \end{aligned}$$

where the subscript *c* designates the computed, and the subscript *o* the observed place.

Both observed and computed places are already referred to the mean equinox of 1894.0. If the observed position were the apparent place we should have to reduce the computed also to apparent place by means of the formulæ

$$\begin{aligned} \Delta \alpha &= f + g \sin (G + \alpha) \operatorname{tg} \delta \\ \Delta \delta &= g \cos (G + \alpha), \end{aligned}$$

the quantities *f*, *g*, and *G* being taken from the ephemeris for the year and date.

If the observed position has not been corrected for parallax we refer it to the centre of the Earth by means of the formulæ

$$\begin{aligned} \Delta \alpha &= - \frac{\pi \rho \cos \varphi'}{\Delta} \cdot \frac{\sin (\alpha - \theta)}{\cos \delta} \\ \operatorname{tg} \gamma &= \frac{\operatorname{tg} \varphi'}{\cos (\alpha - \theta)} \\ \Delta \delta &= \frac{\pi \rho \sin \varphi'}{\Delta} \cdot \frac{\sin (\gamma - \delta)}{\sin \gamma} \end{aligned}$$

where

α is the right ascension, δ the declination, Δ the distance of the planet from the Earth, φ' the geocentric latitude of the place of observation, θ the sidereal time of

observation, ρ the radius of the Earth, and π the equatorial horizontal parallax of the Sun.

For the difference between computed and observed place we have

$$C - O = -2' 37''.7 \text{ in right ascension, and } C - O = -57''.7 \text{ in declination.}$$

By the method just given we have found the positions of the planet for several dates and have compared with the observed places. The comparison shows outstanding differences too large to be accounted for by the effects of the perturbations yet to be determined, which are the perturbations of the second order, with respect to the mass, produced by Jupiter, and the perturbations produced by the other planets that have a sensible influence. We have therefore corrected the elements that have been used in the computations thus far made, by means of differential equations formed for this purpose, employing as the absolute terms in these equations the differences between computation and observation for the several dates. A solution of the equations has given corrections to the elements that produce quite large effects on the computed place. Thus recomputing the position of the planet for the date given above with the corrected elements we find

$$\alpha_c = 340^\circ 33' 44''.5, \quad \delta_c = -2^\circ 2' 15''.6.$$

And since

$$\alpha_0 = 340^\circ 33' 49''.1, \quad \delta_0 = -2^\circ 2' 25''.4$$

we have, for the difference between computed and observed place,

$$C - O = -4''.6 \text{ in right ascension, and } C - O = +9''.8 \text{ in declination.}$$

ARTICLE II.

AN ESSAY ON THE DEVELOPMENT OF THE MOUTH PARTS OF CERTAIN INSECTS.

BY JOHN B. SMITH, Sc.D.

Read before the American Philosophical Society, February 21, 1896.

Since the publication of my paper on the mouth parts of the *Diptera*, printed in the *Transactions* of the American Entomological Society for 1894, I have continued gathering material, have examined the oral parts of a very large number of species of all orders, and am more than ever convinced that in all essentials the conclusions already published by me are correct—revolutionary as they seem at first sight. That my ideas have not found unquestioned acceptance is not surprising; but no one has, to my knowledge, published anything that disproves the points made by me. It has been suggested, however, because I have not made continual reference to the works of previous authors, that I was ignorant of the literature, and several papers have been cited as contradicting my conclusions.

As a matter of fact I believe I am fully aware of all that has been written on the subject, and have, in each case where my attention has been called to a paper, studied it carefully, and found nearly always that the facts given bear me out, though the conclusions are adverse; simply because no author has seriously questioned the universally accepted homology of the mouth parts in the various orders. My own studies have been made on a basis so radically different from any heretofore accepted, that my results must stand on them alone, and my conclusions, if valid, must stand on the facts as they appear to me. I have used principally the dissecting needles in my work; but have not neglected the section cutter. This latter instrument has been rather too much used at the expense of the needles, and its results, though undoubtedly accurate as a record of facts, are easily misinterpreted if the basic homology which is assumed

to exist is inaccurate. For the reasons just given no references to previous writers will be made, except incidentally, and as I have in some respects modified my views as to the homology of certain of the parts, I will go into the entire subject in such detail as is necessary to prove my point; but without reprinting my first paper, which should be herewith consulted.

I do not expect denial at this day, when I claim that no explanation of the homologies of the mouth parts of insects can be considered satisfactory which will not stand the test of criticism by the theory of evolution. If we assume the origin of all insects from one original type, we must, necessarily, assume that all the mouth structures are derivatives of one type, and we must so study them as to be able to explain, step by step, just what specializations have occurred. We may not be able to complete entirely each link in the chain of evidence, but we can, at any rate, reach a result consistent with all the facts known to us. Any explanation which satisfies all the requirements of a regular and natural development is to be preferred to one which demands an unexplained specialization of any part, not in line with its function in other series. It is therefore necessary to study carefully the make-up of every separate mouth organ, and of every sclerite in each, to become thoroughly familiar with its uses and to ascertain the lines in which it varies or develops.

It may be premised that the mouth parts of the *Hemiptera* in their present condition are not included in the range of these studies. I have examined numerous specimens and have devoted especial attention to *Cicada* and *Thrips*—the latter classed as hemipterous for present purposes only—and I believed at one time that I had made out the remnants of a mandibular sclerite, and so published it. Mr. C. L. Marlatt questioned my conclusions and asserted that the mandibles are represented by one pair of bristles. While I believe that I was wrong in my identification of the mandibular sclerite, I am yet convinced that I am correct in claiming that beak and setæ are all maxillary structures. I have concluded, however, after a careful review of all my preparations and of what has been written, that the *Hemiptera* in the mouth structure are not descended from any well-developed mandibulate type, and that no trace of true mandibular structure occurs in any present form.

In other words, the *Hemiptera* equal all the other orders combined in rank, for all others are mandibulate or derivatives from a mandibulate type. The archetypal Thysanuran with undeveloped mouth organs varied in two directions—toward the haustellate type now perfected in our present *Hemiptera*, and to the mandibulate type: and there has never since been any tendency toward a combination. The haustellate type proved ill adapted for variation and there is, in consequence, a remarkable sameness throughout. This kind of structure must be studied on an entirely new basis to

get at the steps by which the present "beak" was developed, and my material is not sufficient for that purpose. The mandibulate type, on the contrary, proved well adapted for variation, and its differences and modifications are here traced.

For convenience, Kolbe's figures of the mouth parts of a grasshopper are reproduced on Pl. III, Fig. 22, and may be referred to in connection with the following explanation.

In a well-developed mandibulate mouth we have, forming an upper lip, the labrum, often notched in front or toothed; but never a paired organ, never with appendages, and never mechanical in function. It is articulated at base to the clypeus and serves to shield or protect the mouth in front; as a matter of fact, not a functional mouth structure at all. It is marked *lbr* in all figures.

More or less intimately associated with it on the inner side is the epipharynx, which is compared in function with the palate of vertebrates, and is furnished with sensory hairs, pegs or pittings. It may be so closely united with the labrum as to form, practically, a part of it, or may be entirely free. If free from the labrum, the epipharynx is more closely united with the other mouth parts, and in such cases its supports go to the mentum or labial structures. Not infrequently it has attachments to both. In form it may be a mere pointed process, or it may be a more or less divided, plate-like organ; but its functions are gustatory or sensory in all cases—it never becomes a functional mechanical structure, and I have never found it without a more or less developed labrum to shield it. It is lettered *epi* in all figures.

Just below these covering and gustatory organs is a pair of mechanical structures—the mandibles—set, one on each side of the head, and attached to the inferior margin of the epicranium or an extension from it. These mandibles are never jointed, rarely bear appendages, and never such as are functional, rarely have a movable tooth, and are usually solid and highly chitinized. They are actually made up of a number of sclerites, laterally united, but distinguishable in certain types like *Copris*, Pl. I, Fig. 8. I have elsewhere named and homologized these sclerites; but as the matter is not in dispute, and of no importance here, a simple reference to the figure in which they are named is all that is necessary. The position of this pair of mouth structures is invariable. They are completely disassociated from the maxillary or labial structures and remain attached to the head when all the other parts are removed in a body. They attach by socket joints to the epicranium and their tendons and muscles attach to its inner surface. They never change in function, never become united with or attached to the other mouth organs and never become internal structures. When not needed for chewing or biting the tendency is to obsolescence: never toward a change into a thrusting or piercing organ, so far as my observations extend.

Below the mandibles are found a pair of maxillæ, made up in all cases of a number of sclerites, and nearly always supplied with palpi or jointed tactile organs. The more particular consideration of these organs and their parts may be somewhat deferred.

Forming the lower lip and closing the mouth inferiorly is the labium, also made up of a number of sclerites and usually furnished with palpi. It is never entirely paired in existing insects, but is assumed to be made up of two more or less united structures, similar in essential character to the maxilla, as has been well stated by Prof. J. H. Comstock. This labium is an exceedingly important structure and forms the oral termination of the digestive tract or the mouth of the œsophagus.

Attached to the inner surface of the labium is the hypopharynx, a variably developed structure, which is supposed to be the remnant of another originally paired organ, the endo-labium. I have never seen the genera in which it is said to be well developed, hence have no well-founded opinion to offer. I find it uniformly a single organ, often highly developed and gustatory in function, sometimes a merely passive structure more or less closely attached to the ligula, usually very near the opening into the digestive tract.

Briefly recapitulated, the insect mouth, when most fully developed, consists of two pairs of lateral jaws moving in a horizontal plane between an upper and a lower lip, which are furnished with gustatory structures forming the roof and the floor of the mouth respectively. This mouth is adapted for biting and chewing and varies to types adapted to lapping, to sucking only, and to piercing and sucking. The problem before me is to ascertain by what modifications these different changes in type have become established.

If we examine the head of a well-developed mandibulate insect from the under side—*Copris carolina*, Pl. I, Fig. 7, may serve as type—we find, centrally, the gula or throat, bounded laterally by the genæ or cheeks, extending to the posterior margin of the head and bearing anteriorly the labium. The labium when carefully dissected out is found to consist of a broad basal plate, the submentum, more or less firmly articulated to the gula and never, in existing insects, a paired organ. It bears anteriorly another plate, the mentum, also a united organ, though sometimes traces of a division are apparent. It is usually smaller than the submentum, sometimes membranous, often entirely separated and frequently so united with the latter part that the two are not separable. Though the submentum is the most persistent and dominant structure it has been customary to use the term mentum to apply to the united sclerites, and it will become convenient for me to so use the term hereafter when no confusion or misunderstanding can be occasioned. The structure is lettered *m* in all the figures.

Attached and articulated to the mentum anteriorly are the central ligula, a pair of paraglossa bounding it, and a pair of palpigers, one at each outer edge, bearing the labial palpi.

The ligula or glossa, marked *gl* in all the figures, is a paired organ only in the more generalized orders, and is usually present as a single, central structure, which may be either chitinous and rigid or membranous and flexible. It is the most persistent of all the labial structures, is never attached except to the mentum, and always has associated with it the hypopharynx where that is present. We always find at its base the opening into the alimentary canal, or oesophagus, as this part of it is termed, and this must ever be the test of labial structures—that they are attached to the mentum and have at their base the opening into the alimentary canal. The association is never broken, and the base of the ligula, whatever its form or however it is modified, always marks this point. On the other hand, by tracing the alimentary canal to its external opening, we can always recognize the ligula by its position, however little it may resemble normal types.

The paraglossæ are sometimes intimately united with the ligula, sometimes completely separated from it: they may be of the same or a different texture; but they always arise from the mentum on each side of and close to the central structure. Their tendency is to obsolescence, but they may become united and form a bed for the ligula which remains the inner organ. Their range of variation is not great; they are never jointed, and never become mechanical structures.

The palpi are tactile in function under all circumstances, though they may lose this function in great part and may, by coalescence, form a sheathing to the ligula. They are never, under any circumstances, attached anywhere except to the mentum, directly or indirectly, and their location must be constantly the same. They cannot, without losing their essential character, become disassociated from the mentum, nor can they ever form an envelope or covering for it, or for the submentum, without a change entirely at variance with any reasonable theory of development. To accomplish this they would first lose their character as labial appendages. In brief, the labium is the external beginning of the alimentary canal, and none of the parts ever lose this association. Whatever their modification, no labial structures can ever be joined to the sides of the head outside of mandibular or maxillary structures.

As an illustration of the most generalized form of labium at present known to me, the roach (*Periplaneta orientalis*, Pl. II, Fig. 16) may be selected. Here we find the mentum with a well-defined impression resembling a suture, and bearing a broad paired structure, from which arise the slender, two-jointed ligula, the broad, fleshy

paraglossæ, and the three-jointed labial palpi. This generalized structure fixes the relation of the parts, and from it we may pass to more specialized types.

In *Harpalus caliginosus* (Pl. III, Fig. 7) we have a case where the ligula forms a single, central organ, laterally bounded and on one side completely enveloped by the softer paraglossæ. The location of the palpi remains essentially the same. We have here two cases showing the change of a two-jointed membranous paired organ into a single, rigid, chitinous structure, and the identity of the parts is not questioned, nor I believe, questionable.

If we carry our dissections one step further and from the fresh specimen remove not only the highly chitinized parts, but also the softer attached structures, leaving maxillæ and mandibles undisturbed, we find in all cases the œsophagus in the cavity below the mentum and submentum, and these sclerites afford attachments for necessary muscles. They also form, by means of chitinous extensions and processes, a chamber or cavity protecting the œsophagus and supplying muscular attachments when a sucking or pumping structure is needed. Thus the mentum and submentum, whether separated or united, are always inferior coverings to the œsophagus. To support this structure, processes sometimes extend almost or quite to the upper or anterior surface of the head, and in many cases, where the epipharynx is separated from the labium, it is connected by means of long processes with the mentum. This is true in many Coleoptera, quite usual in the Hymenoptera, and occasionally found also in the Diptera. In Pl. I, Fig. 6, is a lateral view of the labium of *Copris carolina* when completely dissected out, and the clubbed processes, loosely attached to the inferior prolongation of the submentum, normally support the epipharynx. In Pl. I, Fig. 9, and Pl. II, Fig. 18, we note similar processes in *Andrena vicina* with part of the epipharynx still attached, and in *Polistes metricus*, where the structures are complete. Precisely the same structures occur in *Simulium* (Pl. I, Fig. 1^d), as will be more fully noted hereafter. It may be stated that I have adopted the term "fulcrum," used by Macloskie and others, to designate the structure formed by the mentum and submentum and containing the beginning of the alimentary canal.

In *Polistes metricus* (Pl. II, Fig. 18^b) I show the labium completely dissected out, with all its attachments, viewed laterally. It will be noted that here the mentum and submentum are united, highly chitinized, and form a scoop-shaped structure, bearing at one end the labial structures and enclosing normally the beginning of the œsophagus. Attached by long chitinous rods to the posterior angles is the epipharynx, so that hypopharynx and epipharynx are borne on the same base, are closely opposed to each other and may be manipulated by muscles arising close together. The origin of the palpi is shown from the mentum. On Pl. II, Fig. 18^a, are shown ligula

and paraglossæ of this same *Polistes*. The structures are here membranous, somewhat bladder-like, and well adapted for lapping by means of flattened, bent processes, set in series on the entire inner surface. The paraglossæ are completely separated and the mouth opening is shown at the base of the figure, as well as the chitinous ring marking the beginning of the œsophagus.

In *Andrena vicina* (Pl. I, Fig. 9) we find a similar yet quite different structure, *i. e.*, the same parts, used for much the same purpose, yet considerably modified in detail. The mentum is here much longer, more shallow, but similarly bears the epipharynx on chitinous rods. The ligula is more inflated and the paraglossæ are much reduced, but the palpi originate as before, and we have simply an illustration of the variation in form found in this united mentum and submentum. It is important to note here that in *Polistes*, *Andrena*, and indeed the Hymenoptera generally, the labial structures are free from all lateral attachments to the head and may sometimes be projected forward quite a distance. The attachment to the head, indeed, is muscular and membranous entirely, and there is no direct articulation to any point by chitinous or rigid processes. There is nothing therefore to prevent the growth of the head sclerites around the mentum, which would thus become an internal structure—as has actually happened in the Diptera.

Another feature upon which Dr. Packard rightly places great stress is that a salivary duct opens into the hypopharynx at the base of the ligula, which he thereby identifies. As this ligula is always attached to the mentum, it follows that this structure may be identified in the same way, while no structures not originating from the same point can be labial in character.

Before studying further the specializations of the labial structures, it may be well to say that they sometimes tend to become useless or obsolete, or so much reduced that they are difficult of recognition; and, curiously enough, in such cases the palpi seem to be the persistent organs. Thus in some species of *Scoliidae* among the Hymenoptera the mentum bears only little, feebly developed palpi. A striking case is in the *Panorpidæ*, where on Pl. III, Fig. 4^b, the mouth structures of *Bittacus strigosus* are shown. Here ligula and paraglossæ have disappeared entirely; but the palpi are distinct and the curiously developed hypopharynx marks the beginning of the opening into the œsophagus.

A modification of this type is to be found in the Lepidoptera, where practically in all cases the palpi alone, attached to a plate of variable size and shape, represent the labial structures.

It seems a long jump from the reduced type in *Panorpidæ* to the fully developed labium of the *Apidæ*; yet, except for the fact that all the parts are much elongated,

there is no difference from *Andrena* or *Polistes*, which have been already studied. I have found no species which shows all the parts more fully developed than *Xenoglossa pruinosa* (Pl. II, Fig. 15). Here all the parts are equally developed and all are functional; hence it makes a good starting point. The mentum is not shown in the figure except at the point to which the other parts are attached, and surmounting it centrally, we find the ligula; here a united, though extremely flexible organ. Lying centrally upon it, so as to close a groove, is the hypopharynx, in this case not easily separable from the ligula. Arising close to the central organ on each side are the paraglossæ; almost as long as the glossa itself, flexible, unjointed, flattened and a little incurved at the margins so as to form, when closely applied to it, a partial shield for the ligula. Outside of all, situated at the outer margins of the mentum, are the palpi. These are four-jointed; but the basal joints are enormously elongated in proportion to the terminal two, and they are also flattened out, broadened and infolded, so that when at rest they cover and almost conceal the other labial parts, though not extending forward as far as they. In this insect the structures just described are almost entirely covered by the maxillæ, and a transverse section (Pl. II, Fig. 15^a) is interesting and instructive. It represents the structure at about the middle of the combined maxillæ and labium and illustrates the relative position of the parts.

The tendency in the bees is toward a loss of the paraglossæ, which shorten gradually until they disappear altogether, as represented in a species of *Bombus* figured in Pl. III, Fig. 15. Every intergrade is represented in any good series of bee mouth parts, and in their rudimentary condition, without function, they appear in *Bombus* sp., represented on Pl. III, Fig. 6. The palpi retain their unique development, and in the figure just cited are seen to be as long as the ligula itself, the basal two joints enfolding it almost completely, while the terminal joints are much reduced in size and set near the tip of the second joint, on the outer side. In other species these terminal joints are proportionately yet more reduced and are sometimes difficult to find. The essential point to be noted is that at their best development the paraglossæ are not jointed and that they tend to complete obsolescence in the most highly specialized types. The palpi in *Bombus* require a little further examination: Reference to the figure last cited will show a short segment between the mentum and the first long joint, and this is membranous in texture. The mouth parts in *Bombus* are folded when at rest and the hinge is at the mentum; hence the necessity for some such provision to enable the palpi to bend safely.

Now let us assume that the ligula of this *Bombus* became rigid and chitinized, and that the edges of the palpi enfolding it became united to form a complete cylinder; and then let us examine *Eristalis tenax* (Pl. III, Fig. 5) in the light of this assump-

tion. First let me say that I have already shown that a change from flexible to rigid ligula is not uncommon, and the suggested union of the palpi is a much less violent requirement than that imposed by the current explanation of the Dipterous mouth. Referring for a moment to Pl. I, Fig. 3, we see the entire mouth structure of *Eristalis tenax*. Above is the mentum and submentum, very like the structure already described for *Polistes* and entirely homologous with it, and at its tip we find arising in a group the structures further enlarged at Pl. III, Fig. 5. Centrally we find the now rigid ligula, deeply grooved in the middle, the channel closed by a flattened, also rigid and chitinized hypopharynx. Loosely enveloping this central ligula is a more membranous cylinder, evidently made up of two lateral halves, two-jointed, and the terminal joints separated or paired except at the base. As in *Bombus* the mouth of *Eristalis* is hinged, and the joint is also at the base of the ligula. The latter organ is so articulated as to allow of the flexion; but in the palpi we find again the provision already noted in *Bombus*—a flexible, membranous, pseudo-segment. Now if we section the *Bombus* and *Eristalis* at the middle, we find the cuts alike, except that in *Eristalis* the palpi are completely united over the hypopharynx and closely approximated at the opposite side. If we section near the tip, the cuts in both cases are identical. That this united structure in *Eristalis* is the united labial palpi seems to me beyond doubt. In the first place, the point of origin is normal, next to the ligula and at the tip of the mentum; and, secondly, it is a jointed organ and therefore cannot be paraglossa. It is in all points the structure of *Bombus*, with the terminal joints lost and the two halves united for the greatest part of the distance. That the parts named mentum and submentum are really such, is proved by the fact that the hypopharynx, which is not in dispute, originates from and that the œsophagus originates within it.

In *Bombus fervidus* the ligula is unusually developed and much longer than the labial palpi, while the paraglossæ are wanting. In Pl. III, Fig. 12, is a *camera lucida* sketch of the labial parts of a carefully mounted specimen. The structures here are exactly as normally held when at rest, and only the mentum is a little crushed by the cover glass on the shallow cell. Now chitinize this whole structure thoroughly, and then compare with the drawing of *Chrysops vittatus* (Pl. III, Fig. 13) made in the same way. The magnifications are different, of course, the *Bombus* being drawn at short range with a four-inch lens while the *Chrysops* was drawn at long range under a one-inch objective. The object was to get the two of approximately the same size for convenience of comparison. In the Tabanids the mouth parts are rigid and not flexed, and no sort of joint or hinge is required; hence the structures are all rigidly united at the base to the mentum. In *Bombus fervidus* the palpi are reinforced by a heavier

chitinous rod a little to one side of the middle, and just this sort of structure we find everywhere in the Tabanids, lying outside of the ligula at base, articulated to the outer edge of the mentum. This, in fact, first led me to suspect the true nature of the structure. If now we section *Bombus* and *Tabanus* near base, the cuts will be alike, save that the palpi in the latter are united at one margin. If the cuts are made toward the tip, the sections are alike—ligula and hypopharynx alone appearing in both cases. We have then, in *Chrysops* also, a complete labium, save that the paraglossæ are absent and the palpi are united on one edge.

In the *Simuliidæ* are many interesting species with generalized mouth structures, and of these I have studied the "Buffalo gnat," from material kindly furnished by Dr. Riley, an undetermined *Simulium* sent me in numbers by Prof. Aldrich, and an undetermined little midge collected by me at Anglesea, N. J. The species are practically identical in the labial structures, and here again the mentum and submentum strongly recall *Polistes* and other Hymenoptera. The hypopharynx is well developed and the ligula are nearly divided; but I have no satisfactory sections of this insect and the relations of the parts are not clear to me. At Pl. I, Fig. 1^b, the labium of the "Buffalo gnat" is shown. In the species sent by Prof. Aldrich I succeeded in getting a dissection illustrating the connection of the epipharynx with the mentum, and this is illustrated at Pl. I, Fig. 1^d. This is really an exceedingly interesting specimen and it clears up the relation of the frontal prolongation of the mouth. That the structure so labeled is really the epipharynx there is little room for doubt, and the location of the little, chitinous, toothed processes, and their character, leaves no doubt in my mind that they are mandibular rudiments—exactly as I claimed in my first paper. That they can be dermal appendages, as has been claimed, does not seem reasonable to me. They are too highly chitinized in comparison with their surroundings, and why should they so completely resemble miniature mandibles? I do not know of any case of dermal appendages of a similar character, and it is at least passing strange that such should be developed exactly where, normally, mandibular rudiments might be reasonably expected.

The tendency in the piercing Diptera is constantly in the direction of simplicity of labial structures, and so we gradually note the loss of all trace of accessory labial structures, leaving the ligula and hypopharynx as sole representatives. In the *Asilidæ* there are no other attachments to the mentum, as shown in Pl. III, Fig. 1^c.

These apparently single structures are sometimes interesting in section, as appears in *Stomoxys calcitrans*, Pl. I, Fig. 11. Here the cut shows two crescent-shaped structures connected at one edge by the thinnest kind of a chitinous shell, and closed opposite by a hypopharynx, which is almost tubular in structure.

Very interesting is the modification found in the *Empidæ*, illustrating the extreme in the loss of parts; for here the hypopharynx is also wanting, though the salivary duct remains, opening into the grooved ligula, as shown in Pl. III, Fig. 2'. In this case the hypopharynx is replaced by an extension and peculiar modification of the labrum. This sclerite is elongated so as to extend to the tip of the labium, and is very much dilated, somewhat bulb-like at its base. In Pl. III, Fig. 2', labrum and ligula of *Rhamphomyia longicauda* are seen from the side, while in Pl. II, Fig. 13, are shown the same structures in *Empis spectabilis*. The edges of the labrum are turned under sufficiently to leave a central channel just large enough to receive the ligula, with which it then forms a closed tube through which the food is taken.

In most of the Muscid flies we find a structure approximating *Eristalis* with the labial palpi removed; and the parts may be longer, or shorter, or differently developed, while adding nothing to what has been already shown; they are, essentially, reduced piercing structures, no longer functional.

We have, however, in certain other species, where the mouth structures are short, very poorly developed labial structures. So in *Hermetia mucens* (Pl. III, Fig. 14) the broad and large mentum bears only a short, scoop-like ligula. The specimen from which the figure was made was somewhat distorted in mounting and the ligula is turned just half round. Similar structures occur in the *Bibionide*, and *Euparyphus bellus* (Pl. I, Fig. 12) is not essentially different.

Heretofore the hypopharynx has been referred to mainly in species in which it was feebly developed and played but a passive part as a covering structure. It is sometimes a highly specialized sensory structure, though it varies greatly, even when functional.

A very curious type is found in *Bittacus* (Pl. III, Fig. 4^b), where it takes the form of a simple cylindrical process, set with spines, almost like an odd joint of some slender palpus. In *Copris carolina*, Pl. I, Fig. 4, showing the epipharynx, may be accepted as a fair representation of the hypopharynx as well, save that the latter is on a much reduced scale. The opening of the salivary gland is in a dense mass of specialized spinous processes.

In the *Libellula*, among the dragon flies, we have an inflated, somewhat tongue-like organ (Pl. I, Fig. 10^b), in which the salivary duct is plainly traceable to its opening among a mass of crossed, specialized spines. The surface is richly supplied with sensory pittings and tactile hairs. It is a great modification from a structure of this kind to the simple, ribbon-like form of *Bombus*, or the flat, slender, chitinous form in *Tabanus*; but the intermediate stages are all present.

To recapitulate concerning the labial structures. The mentum and submentum

cover the oesophagus. They may be united so as to form a single organ, and their tendency is to become internal head structures. The ligula has at its base the opening into the alimentary canal; it is rarely paired, may be rigid or flexible, and has closely associated with it the hypopharynx, recognizable by the salivary duct which it shelters. The paraglossæ arise on each side of the ligula or glossa, and may be chitinous or membranous. They are never jointed, never developed for any specific mechanical purpose, and their tendency is to become obsolete. The labial palpi are essentially tactile and never become mechanical save as they may form a covering or sheath for the ligula.

From the most generalized type found in the *Blattidæ* the modification is first from a divided to a single ligula; next to a disappearance or obsolescence of the paraglossæ; later the labial palpi also disappear, and finally the hypopharynx is also dispensed with. There is no break, and nowhere is there any violent change of structure or function.

We are now ready to take up the maxillæ, which, though composed of a larger number of sclerites, are usually more easily understood in the ordinary type of mandibulate insect. The organ is usually paired and never so completely united as the labial structures. The two parts are always external to the labium, which it is their tendency to enfold, and they never have any direct connection with the alimentary canal. Though the maxillary structures tend to form a covering or sheath for the labium and its appendages, there is never any intimate connection between them. No part of the maxilla ever unites with any part of the labium or with any of its appendages. The maxillæ are essentially mechanical structures, and their range of variation is sufficiently great to meet the most diverse possible demands made upon them. A distinct and fundamental characteristic is the fact that each set of sclerites has its own peculiar possibilities and limitations, and once these are understood the most highly specialized type becomes simply explicable.

On Pl. III, Fig. 17, is a copy of Prof. Comstock's figures of *Hydrophilus*, showing the maxilla from both surfaces, and these may conveniently serve as a text to explain the sclerites composing it. At the base is the cardo or hinge, giving attachment to muscles and tendons articulating it to the head. It is to be noted that there is no firm or chitinous articulation to any head sclerite, and except by muscles or tendons no direct attachment. This we found the case also in the labium in the more specialized forms, and in the Hymenoptera, for instance, labium and maxillæ together are easily dissected out without cutting any but muscular tissue, and without breaking any chitinous connections or joints. This is in marked contrast with the mandibles which, when functional, are always firmly articulated by chitinous joints to the external

head sclerites. Supported upon the cardo is the stipes or foot-stalk, deriving its muscular attachments largely from the cardo; but to some extent from the head itself, and this feature is a variable one. Surmounting the stipes is a palpifer or palpus-bearer, to which is attached a palpus, varying in the number of its joints. This derives all its muscles from the stipes in the typically developed maxillæ. On the inner side of the stipes is attached the subgalea, deriving its muscles from the head in large part; and this bears a two-jointed galea or hood. It is a matter of some importance to note that this galea is never more than two-jointed under any circumstances, and that the tendency is to maintain that number; though in many instances it is reduced to one only. It is the most persistent as well as the most variable of the maxillary structures, and is present when any of them exist at all. Inside of the subgalea, and attached to it as a rule, is the lacinia or blade, which may or may not bear a digitus or finger. In the figures just cited we find what may be termed a normal or proportionate development of all the parts, in which no one sclerite is unduly developed or specialized. Before attempting to study specializations it is important to note that, when carefully examined, the sclerites are seen to be arranged in three parallel series. That is to say three separable parts have grown together laterally, and this union bears with it the possibility of future disunion or separation for special purposes. We have as the inner series lacinia and digitus; as the middle, subgalea and galea; and as the outer the cardo, stipes and palpifer with the attached palpus. Now if we examine some of the Neuroptera, *e. g.*, *Sialis* (Pl. III, Fig. 16), we find this lateral arrangement very strongly marked, and it is easily understood that each of these parallel sets may have their own peculiar limitations, and that each may be separately and independently modified.

But lest this seem, after all, a far-fetched conclusion, let us examine the maxillæ of *Bittacus strigosus* (Pl. III, Fig. 4^b), and we find almost exactly the hypothetical state of affairs actually existing! Lacinia, galea and palpifer all separated, of nearly equal length, but of quite different appearance. The appearance of a transverse section made at about the middle is shown as Fig. 4^c. For a generalized type this form is especially valuable, and we may fairly use it as a guide in our discussion of maxillary possibilities.

There is no absolute rule in the matter, but usually the galea tends to become the dominant maxillary organ. In many Neuroptera, and especially in their larval stages, the lacinate structure is best marked, as illustrated in Pl. III, Fig. 9, representing the maxilla of a Perlid larva. Here the galea is reduced to a subordinate rank, and in many predaceous Coleoptera it is truly palpiform.

In many Orthoptera the development of the galea justifies the name by forming

an almost complete hood over the lacinia. This is well illustrated in the maxilla of the oriental cockroach, *Periplaneta orientalis*, shown at Pl. III, Fig. 8. At this point a comparison of the figure just cited with the galea of *Simulium* (Pl. I, Fig. 1^a) will prove interesting and instructive.

In the Hymenoptera the galea dominate throughout; no elongated palpifer is ever developed, and indeed the maxillary palpi are sometimes almost rudimentary in the Apidæ, as shown at Pl. III, Fig. 15.

In *Polistes*, illustrated at Pl. II, Fig. 18^c, we find a common type of the *Vespidæ*, where the lacinia forms a small, blade-like structure, free for almost its entire length, and the maxillæ as a whole shelter a large part of the labium. In those cases in which the "maxillæ" are elongated, the galea is usually the organ affected.

Thus in many Meloids among the Coleoptera we have the mouth parts elongated, and a study of the maxilla of *Nemognatha* (Pl. III, Fig. 20) shows at once the sclerites concerned. Here the lacinia is much reduced, and if we remove it altogether we have the normal Lepidopterous maxilla, which tends to a locking together to form a complete tube. Recently it has been found that in certain Lepidoptera the lacinia are actually present, and the figures which I have seen indicate a structure in all essentials like that of *Nemognatha*.

While speaking of the Lepidoptera it may be well to cite *Pronuba* (Pl. III, Fig. 21), in which the palpifer is elongated in the female and highly specialized into a sensory and tactile structure, though unjointed. In a well-prepared specimen the point of origin is perfectly clear, and it is entirely homologous with the structure seen in *Bittacus*. In the male (Pl. III, Fig. 19) the "tentacle" is not developed, though the palpifer is enlarged to some extent.

In the *Apidæ*, among the Hymenoptera, the lacinia disappear entirely in extreme cases, or are at least greatly reduced, while as already stated the palpi are sometimes scarcely visible. The galea, on the other hand, is very prominently developed, and when at rest envelopes the ligula and paraglossæ almost completely. In Pl. III, Fig. 15, is represented the usual appearance of all the parts separated, while at Pl. II, Fig. 15^a, the transverse section of the mouth structures of *Xenoglossa pruinosa* shows their normal relation when at rest. It is seen that the galea actually overlap somewhat at one margin, and a union along this line would be scarcely considered a violent stretch of the range of variation. Assume such a union, eliminate the paraglossæ which are organs tending to obsolescence, and then compare with the transection of *Eristalis tenax* (Pl. I, Fig. 3^d). If the palpifer be eliminated from this latter figure the cuts are practically identical.

Returning to our figure of *Bombus* (Pl. III, Fig. 15), we note at the outer edges

of the galea a series of ridges which, under a high power, look extremely suggestive of the structures found in the labellæ of Diptera, especially where, as for instance in *Bombylius*, the pseudotrachea are imperfectly developed. These ridges vary much in the species; but are particularly marked in a little *Andrena* near *vicina*, if not that species itself. Here we see (Pl. III, Fig. 3) the entire inner face clothed with a thin membrane which is crossed by numerous closely set fine chitinous lines! I claim that this structure is the homologue of the pseudotracheal structure in the Diptera, and that in the latter order it is in the galea that the development occurs, as it does here in the Hymenoptera. The relative differences in size are not of importance. As to the particular use of this structure in *Andrena* I have no suggestion to make.

In the Proceedings Ent. Soc. Washington, Vol. III, Mr. Ashmead figures on Pl. III, some very suggestive mouth structures of parasitic Hymenoptera, of which that of a Pteromalid is reproduced on Pl. III, Fig. 18. The central labium with its attached structures is much reduced in size, and the maxillæ, bearing the well-developed palpi, are reduced to a single structure, the galea, resting upon what may be considered the stipes. Now if we bring these two parts of the maxillæ a little more closely together, we have almost the exact structure seen in *Bibio* (Pl. III, Fig. 11^b). The basal ring, bearing the palpi, corresponds almost exactly to the basal ring of *Pteromalus* except for size, while except that the surmounting galea are two-jointed, the correspondence with the upper portion of the structure is equally marked. The labium in *Bibio* is much like that figured in Pl. III, Fig. 14, for *Hermetia*, and in Pl. I, Fig. 12, for *Euparyphus*.

I am making no very risky statement when I assert that the sclerite to which the maxillary palpi are attached must of necessity be maxillary; and further, it is equally safe to say that no maxillary sclerite can bear a labial appendage: and certainly not a labial palpus. It would be an absurdity, contrary to all the laws of a natural development, for a modified labial palpus to become attached to the sclerite bearing also the maxillary palpus; while if we consider it the two-jointed galea, its position is normal, requires no assumption of change or character, and does not differ in any essential points from the gale of the roach (Pl. III, Fig. 8). Yet these two joints in *Bibio* will, with a ridged membrane thrown over them, represent the labellate tip of the Muscid proboscis. That such a ridged membrane is well within the range of galear variability we found in the *Andrena* near *vicina* (Pl. III, Fig. 3).

The structure in *Euparyphus bellus* (Pl. I, Fig. 12) resembles *Pteromalus* yet more closely, in that a single ring only surmounts the segment bearing the palpus. In this instance the maxilla is reduced to exactly the same segments seen in the Hymenopteron, and logic demands that we recognize them as the same. In this case, how-

ever, the lower ring is complete—*i. e.*, the two halves of the stipes have become united. That it must be stipes is shown by the fact that it bears the palpus, and again the surmounting sclerite must be maxillary also.

There are other species allied to those already cited in which similar structures occur; but I need for the present call attention to only one more; a species of *Olfersia* (Pl. II, Fig. 19). Here the ring is complete in front, but broadly open behind, and bears the chunky, single-jointed palpus. Surmounting is a single sclerite, very much resembling in appearance that of *Pteromalus*, and undoubtedly homologous with it. Of course *Olfersia* is parasitic in habit, and the mouth parts are specialized for blood-sucking; but the sclerites composing them are nevertheless derived from the same source as in the "higher" types.

I have several times referred incidentally to *Simulium*, and of this the glear structures are figured (Pl. I, Fig. 1^a). Dissecting the parts out carefully we find an almost complete ring at the base, the stipes, to which the palpus and palpifer are attached. Surmounting this is a pair of sclerites, each almost a half cylinder, representing the subgalea, and bearing the two-jointed galea. Here again I claim that the three joints just referred to *must* be maxillary because they are directly articulated to the sclerite bearing the maxillary palpi, and the labial structures are all shown at Fig. 1^b.

A step in the direction of union we find in the Anglesea gnat or midge—also a Simuliid, to which reference has been already made. Here we see (Pl. I, Fig. 2^a) the subgalea united most of their length at one side, while the glear joints are yet free. The basal stipes is not figured because none of my specimens showed it clearly; but the palpifer, palpus and lacinia, as they are connected with it, are shown in the specimen.

In the *Asilidæ* we find another suggestive structure, studied in the light of the facts already set out. Here we see, as illustrated Pl. III, Figs. 1^a and 1^b, the basal stipes well developed, united posteriorly, but separated in front. The palpifer and its attached palpus are situated at the sides, clearly articulated to the stipes, whose character is thus fixed. Attached to this stipes is a broad, infolded structure, united behind but open in front; maxillary because of its attachment to the stipes, and subgalea from its location. It bears in orderly sequence the two-jointed galea of which the terminal joints are free. The species of the *Asilidæ* are large and easily dissected, and the figures were drawn from a species of *Laphria*. The attachments are but little different in the species, and as the figures illustrate the structure from both front and rear, the position of the joints should be clear. These figures will be again referred to in another connection.

In all the species heretofore cited the galear joints were more or less distinct and the pseudotracheal system was little or not at all developed. As the face of the joints becomes covered by a ridged membrane the texture of the entire structure changes. It becomes less chitinized, and the chitine is not evenly distributed, causing sutures to become indistinct and poorly marked. Yet, keeping in mind the general line of variation, we can usually reach a correct conclusion.

In a Leptid, species unknown, we find the appearance shown in Pl. II, Fig. 1. Here there is a united basal plate, covered on one surface with a membrane, and from the chitinous portion arises the palpifer with its attached palpus. Surmounting the chitinous base are two joints, the galea, the chitinous parts of which only are shown in outline, the balance of the space being covered by membrane. Here again the attachment of the maxillary palpus to the basal sclerite determines the maxillary character of all the sclerites directly articulated to it.

In *Hermetia mucens* (Pl. II, Fig. 17) the entire structure is much more membranous, yet the basal chitinous plate is paired, and while the parts are shown in a distorted position, the two galear joints and their relation to the basal, palpus-bearing structure is yet perfectly obvious. The other maxillary structures have completely disappeared, while what is left of the labium is seen at Pl. III, Fig. 14.

The mouth parts in some species of *Tipula* are interesting, and a fair illustration of one of the "snub-nosed" species is seen at Pl. I, Fig. 5. Here the origin of the palpus at the immediate base of the chitinized part of the labella indicates its character, and if we divest the chitine of the surrounding membrane we get the appearance shown at Fig. 5^a. Practically we have a completely paired organ, the relations of which are perfectly simple when the confusing and unimportant membrane is removed.

The peculiar relation of labrum and labium in the *Empidæ* has been already noted, and this makes it easy to separate off all the other parts adhering to the margin of the head, but not in any way connected with the labium. The relation of the parts to each other in *Empis spectabilis* is shown on Pl. II, Fig. 13, while on Pl. III, Fig. 2', are shown the maxillary structures of *Rhamphomyia longicauda*. In this latter figure we note that the parts, except palpifer, are entirely membranous. From the basal sclerite the palpi arise so as to form only a continuation of the membrane itself with an extremely slight attachment to the chitinous palpifer; and to this very same membrane there is articulated by a slightly thickened suture the subgalea, united posteriorly, but separated in front; and this bears in turn the indistinctly segmented galea. This entire structure obviously belongs together and is one organ—necessarily the maxilla.

A very similar structure is found in *Chrysops* (Pl. II, Fig. 14) and in other species

of the *Tabanidae*. Now it will be remembered that in this genus I showed the connection of all the labial parts with the mentum, where they normally belong; hence all the other parts must be, of necessity, maxillary. So we find also in Pl. II, Fig. 14, that the central labellate structure, two of the piercing structures and the maxillary palpi all arise from a single united basal sclerite, the stipes.

In *Eristalis tenax* (Pl. I, Fig. 3) these labellate structures are shown, turned aside to expose the labial structures. Here also I showed the presence of labial palpi in close connection with the ligula and hypopharynx, normally attached to the mentum, and again it follows that the other structures must be maxillary. Again also I must call attention to the fact that the palpi are mere continuations of the enveloping membrane, and that this membrane continues without break to the tip of the labella. Unless we are to believe that a continuous membrane may give rise to both the maxillary and labial palpi, we cannot possibly consider the labella as labial structures.

I have now traced out what seems to me a continuous development of the modifications of the subgalea and galea, and have shown, I think, that from *Pteromalus* in the Hymenoptera to *Eristalis* in the Diptera, a continuous chain may be constructed, requiring nowhere any change of character, function or location. No disassociation from other maxillary structures and no connection with labial structures.

In taking up the modifications of the palpifer I am confined almost entirely to the Diptera, in which this sclerite is best developed. In *Bittacus* I showed its development to an elongated structure of no particular type or function and of about the same texture as the galea. In *Pronuba* I showed its development into a highly specialized "tentacle," tactile and sensory as well as mechanical in character. In the Diptera it is quite usually present as an elongated, rigid, chitinous organ adapted for piercing. It occurs in all the piercing types and is present as a rudiment in many others. It undergoes a curious and interesting change in function as the Dipterous mouth changes from the piercing to the scraping or lapping type, and as it becomes flexed.

The simplest form occurs in those piercing Diptera in which the proboscis is not flexed. Thus in the Buffalo gnat (Pl. II, Fig. 9) it is a stout, semicylindrical piercing organ, enlarged both at base and at tip, at which latter point it is also toothed. The connection of the palpus with the subgalea was already shown on Pl. I, Fig. 1^a, and this shows how the chitinous palpifer forms part of the combination. The palpifer arises, normally, outside of the galea; yet at the tip it is found in connection with all the other piercing structures inside of that organ. How it gets there is illustrated in the Anglesea Simuliid (Pl. I, Fig. 2^a), where all the maxillary parts are shown in proper connection, and it is seen that the palpifer enters the galeal envelope in the

incomplete articulation between galea and subgalea. By separating off the galear structures, the relation of palpifer and lacinia in *Simulium* is illustrated (on Pl. I, Fig. 1^c), and the convergence of the two at tip is not distortion, though perhaps a little exaggerated by pressure. The result of this change of position is that a section made near the base of the proboscis would show as illustrated on Pl. I, Fig. 2^b, while one made nearer the tip would show as in Fig. 1^d. Incidentally it will prove interesting to compare these sections with that of *Bittacus strigosus* (Pl. III, Fig. 4^d), leaving out of consideration the abnormal labium of the latter. The resemblance is perfect, and the resemblance expresses fully the actual condition of the matter. A very similar state of affairs exists in the *Asilidae* (Pl. III, Fig. 1^a). Here the palpifer is the only maxillary piercing organ, and the figure itself shows clearly how easily it would swing inside the ample space left in the subgalea for its entrance. The curvature of the organ is such, also, that when in place it meets the central ligula so as to form a solid puncturing organ.

So in *Chrysops* (Pl. II, Fig. 14) the structure is seen to be similar to that in *Simulium*; but here, as almost everywhere else in the order, it is cylindrical or nearly so, in marked contrast with the lacinia, which is always flattened.

As we get into types that have lost the piercing habit, the function of the palpifer fails or changes. If the species have a short, nonflexed proboscis, it simply dwindles from disuse. So in *Stratiomyia* and in *Leptis* (Pl. II, Figs. 1 and 2) it simply forms a little chitinous appendage to the palpus—a mere remnant without function. If, on the other hand, the species are able to flex the proboscis, another change takes place. There is needed then some lever to which muscles for flexing can be attached, and no structure seems to have been so easily adaptable as the palpifer. So we find in the *Empidæ*, where only slight flexion is required, only a small basal extension, shown at Pl. II, Figs. 4 and 3, for *Empis spectabilis* and *Eulonchus tristis*, and at Pl. III, Fig. 2^b, for *Rhamphomyia longicauda*.

In the *Bombyliidæ* is a step forward. The insects are not predaceous, have the habit of hovering over flowers and using the proboscis in feeding in that position. This requires a much better control, and as a result the basal extension is much better developed, as shown in Pl. II, Figs. 6 and 7, illustrating *Bombylius* and *Anthrax*.

As we get into types like *Eristalis* and other *Syrphidæ*, the basal extension becomes the most prominent and the piercing portion diminishes in size (Pl. II, Fig. 5), and keeping step with this modification is a gradual separation of the palpus itself from the palpifer. This is well illustrated both in *Eristalis* and *Sphaerophoria*, and this tendency continues until in *Lucillia* (Pl. II, Fig. 10) the separation is complete, though the piercing portion of the palpifer is yet distinguishable. In *Calliphora* even

this disappears and the chitinous rod is entirely disassociated from the palpus. Finally in *Stomoxys calcitrans* (Pl. II, Fig. 12) there remains nothing to indicate the existence of any relation between the slender chitinous rod and the distant maxillary palpus. It is not in the least strange that guesses as to the character of this structure in *Musca domestica* should have been so often wide of the mark; though with a proper series as now shown, its origin is clear.

There remains to be accounted for the lacinia, and this in the Diptera is the flat, blade-like structure generally identified as the mandible. It has been shown that while the lacinia is often the dominant organ in many mandibulate insects, the tendency is, on the whole, to a decrease in size, ending in the Hymenoptera in its entire elimination. In the Diptera it is present in the blood-sucking species only, and it may be identified by its position and its relation to the other maxillary structures. It has been several times referred to incidentally, and in the Anglesea Simuliid (Pl. I, Fig. 2^c) its relation to the other maxillary parts is shown. In Pl. I, Fig. 1^c, is illustrated the connection between the palpifer and lacinia in the *Simulium* sent me by Mr. Aldrich. This connection is not fanciful but actual, and no sclerite so intimately connected with an admitted maxillate structure can be anything but maxillary.

Again in *Chrysops* (Pl. II, Fig. 14) I have illustrated the fact that all the structures which I consider maxillary have a common origin. At Fig. 14^c I show the lacinia alone, and it is to be noted that at the base it is modified for attachment with reference to the palpus. Now unless this is a maxillary sclerite, why should it be modified to accommodate the maxillary palpus? Does it not seem rather absurd to believe that this can be a mandible brought to originate from one point with the palpifer and modified to allow it to envelope at base the maxillary palpus?

One of the most serious difficulties in the way of the proper understanding of the mouth parts of haustellate insects has been the desire to provide for the mandibles on the theory that they are among the permanent structures. Yet I cannot understand why this should necessarily be the case. When functional, mandibles are essentially chewing or biting organs, and when the insects do not require such structures, it seems to me most natural that they should become obsolete: and that is exactly what has occurred according to my reading of the facts. Their functional character never changes; they simply dwindle from disuse and gradually disappear. So we find them in the Lepidoptera as mere rudiments, connected with a highly specialized maxilla; and in the Rhynchophora they are sometimes mere remnants, occasionally reversed in position—exactly as I pointed them out in *Simulium*. I think that in view of all the evidence presented by me, none of the piercing organs of the Diptera can be considered mandibles, and I cannot even yet, after carefully weighing all that Dr. Packard

has written, see any reason why the rudimentary structures at the tip of the labral extension in *Simulium* are not mandibles.

If we refer back again for an instant to the Panorpids we note (Pl. III, Fig. 4^a) that in *Bittacus strigosus* the origin of the mandibles form an extension of a lateral head sclerite, with the labrum-epipharynx between them. In *Panorpa* the mouth structures are much shorter, set on an immensely elongated stipes, and at the tip of the frontal extension of the head we again have the mandibles, much reduced, with a small, lappet-like labrum-epipharynx between them. Now the situation of the rudiments in *Simulium* corresponds almost exactly with that of the undoubted mandibles in *Panorpa rufescens* (Pl. III, Fig. 4^c); but in the *Empidæ* we find a yet more closely allied structure. I have already called attention to the peculiar elongation of the front of the head in this family, and now if we examine this at tip, in *Empis spectabilis* (Pl. II, Fig. 13^a) its very close resemblance to *Panorpa* is at once evident. We find a central lappet-like structure with a sensitive surface, which looks like and logically should be the epipharynx, and moving below it is a pair of appendages which, in my opinion, represent mandibles. They are membranous and probably not functional; but this is no argument against their character. I believe that the similarity in the appearance between Pl. III, Fig. 4^c, and Pl. II, Fig. 13^a, is the expression of a true homology, and that mandibles in the Diptera exist in no other form or situation. It is likely that other species, showing them much more perfectly, will yet be discovered; but so indeed do I believe that labial palpi, properly connected with the mentum, will yet be found, so distinct in character that, even if not functional, their homology cannot be mistaken.

Labrum and epipharynx have been frequently referred to in the course of this paper, and in the introduction the general relation of these two parts has been explained. Both structures occur in many families of the Diptera. As in the case of the hypopharynx, the epipharynx has always connected with it a salivary duct. In its intimate connection with the labrum it is shown on Pl. I, Fig. 10ⁱ, illustrating the epipharynx of *Libellula*. Here the chitinous tube giving passage to the duct is fully shown. As an example of a highly developed structure, the epipharynx of *Copris carolina* is shown (Pl. I, Fig. 4), and here the salivary duct opens among the dense central mass of spinous processes. The epipharynx of *Polistes* was referred to in the description of the labium, as was that of *Andrena* in the connection. In the Hemiptera the labrum and epipharynx are usually well developed and the salivary duct is in many cases very well marked.

Among the Diptera some of the larger *Syrphidæ* have the labrum quite distinct, and on the under surface is a sensitive surface into which an obvious duct, with chit-

inous protecting margins, is led, as shown on Pl. III, Fig. 10. A much better developed organ, strongly resembling that in some of the Hemiptera, we find in the *Asilidæ* (Pl. III, Fig. 1^a), and here also the salivary duct is obvious. The structure in *Simulium* has been already referred to, as has that in the *Empidæ*.

To recapitulate concerning the maxillæ: The sclerites form three series, each of which has its own possibilities of development. The lacinia never develops into anything other than a chewing or piercing organ and always arises inside of the galea. The galea varies in the direction of forming an enveloping organ for all the other mouth parts, and the subgalea eventually unites along one margin for that purpose. There is a tendency to develop a ridged membrane on the inner surface of the galear joints which culminates in the pseudotrachea of the muscid labella. The palpifer has a small range of development, from an unjointed, flexible, tactile organ, to a rigid, piercing structure; and as this becomes useless, to a process for the attachment of muscles used to flex the proboscis.

It remains only to acknowledge the assistance received from my entomological friends. Dr. S. W. Williston has from time to time sent me such specimens as I thought might help me; Mr. C. W. Johnson has given me numerous species of families selected because of apparent differences in the mouth structure; and to Mr. J. M. Aldrich I owe many other species in some numbers, among them the Simuliid already referred to. Mr. E. P. Fell kindly sent me specimens of *Panorpa* and *Bittacus*, which enabled me to make a much more complete study of these insects than would have been otherwise possible. To all these gentlemen, as well as to the others who have in any wise aided me, I desire to express my thanks.

Concerning the figures—most of them are *camera lucida* drawings. A few are drawn from micro-photographs, assisted by the specimens themselves. The figures of transections are largely made from actual preparations; some are redrawn from other sources, while a few are ideal.

EXPLANATION OF THE PLATES.

The lettering of the parts, the same throughout, and the abbreviations, are as follows: *Lbr*, labrum; *epi*, epipharynx (the two sometimes combined as *lbr-epi*); *md*, mandible; *car*, cardo; *st*, stipes; *pfr*, palpifer; *mp*, maxillary palpus; *gal*, galea; *sg*, subgalea; *lac*, lacinia; *dig*, digitus; *sm*, submentum; *m*, mentum; *gl*, ligula or glossa; *par*, paraglossa; *lp*, labial palpi; *hyp*, hypopharynx.

Plate I.

- Fig. 1. Buffalo gnat. 1^a, galear structures with palpi attached; 1^b, labial structures; 1^c, lacinia and palpifer of Simulium from Aldrich; 1^d, labrum and labium of Simulium from Aldrich; 1^e, transverse section through middle of mouth of Buffalo gnat.
- Fig. 2. Simulium from Anglesea, N. J. 2^a, the maxillary structures in their actual relation to each other; 2^b, transverse section of mouth parts toward the base of subgalea.
- Fig. 3. Mouth parts of *Eristalis tenax*. 3^a, transverse section of same at the middle of subgalea.
- Fig. 4. *Copris carolina*, epipharynx.
- Fig. 5. Mouth structures of *Tipula* sp.; 5^a, the chitinous parts of the same.
- Fig. 6. *Copris carolina*; labial structures dissected out and seen from side.
- Fig. 7. *Copris carolina*; chitinous part of under side of head.
- Fig. 8. *Copris carolina*; mandible with the sclerites named and homologized.
- Fig. 9. *Andrena vicina*; labial structures, with part of epipharynx attached.
- Fig. 10. *Libellula* sp. *a*, the epipharynx; *b*, the hypopharynx.
- Fig. 11. *Stomoxys calcitrans*; transverse section through the middle of the ligula.
- Fig. 12. Mouth parts of *Euparyphus bellus*.

Plate II.

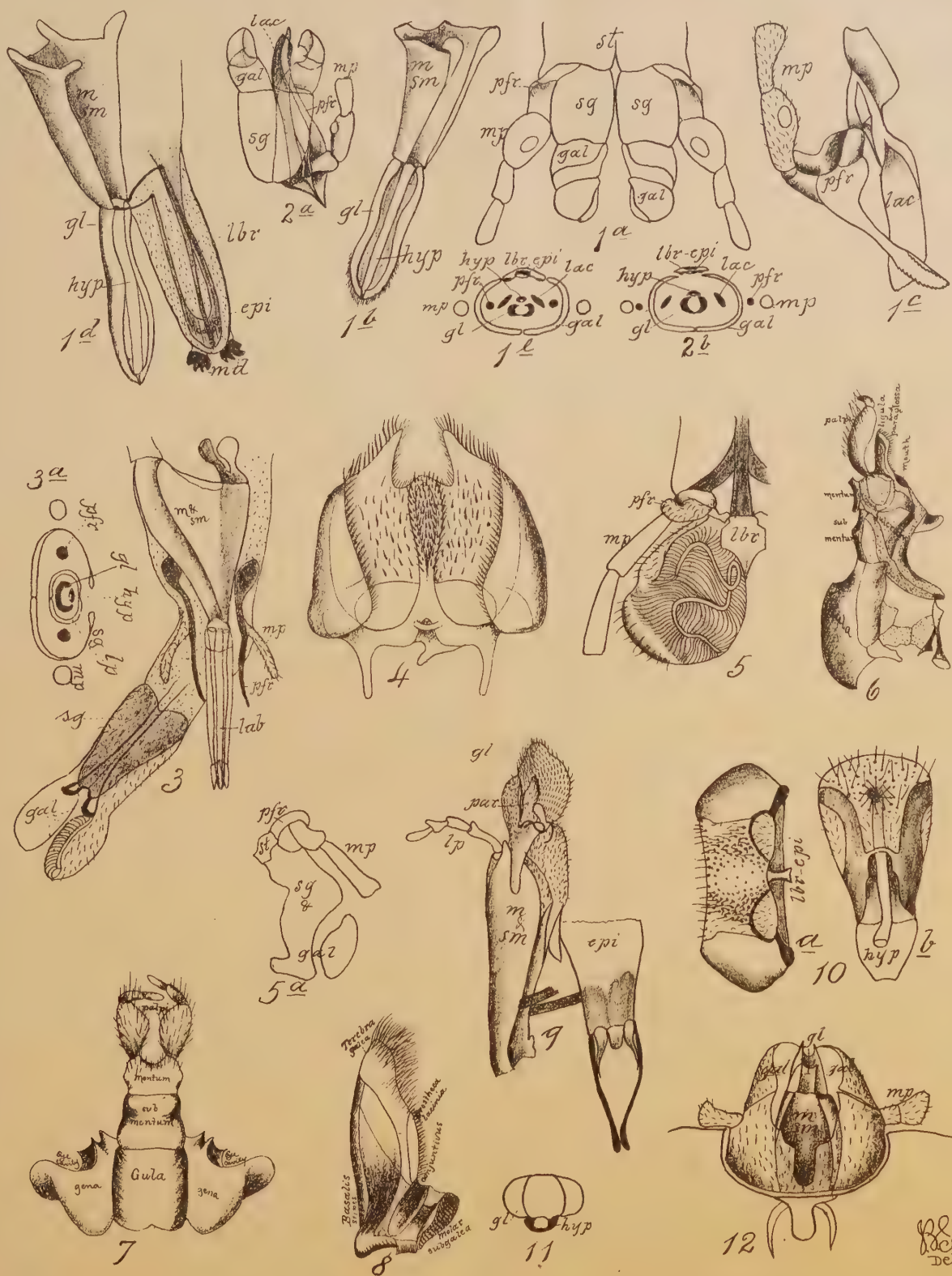
- Fig. 1. Maxillary structure of *Leptis* sp.
- Fig. 2. Palpifer of *Stratiomyia*.
- Fig. 3. Palpifer of *Eulonchus tristis*.
- Fig. 4. Palpifer of *Empis spectabilis*.
- Fig. 5. Palpifer of *Spharophoria cylindrica*.
- Fig. 6. Palpifer of *Bombylius*.
- Fig. 7. Palpifer of *Anthrax*.
- Fig. 8. Palpifer of *Chrysops vittatus*.
- Fig. 9. Palpifer of *Simulium*.
- Fig. 10. Palpifer of *Lucilia*.
- Fig. 11. Palpifer of *Calliphora*.
- Fig. 12. Palpifer of *Stomoxys*.

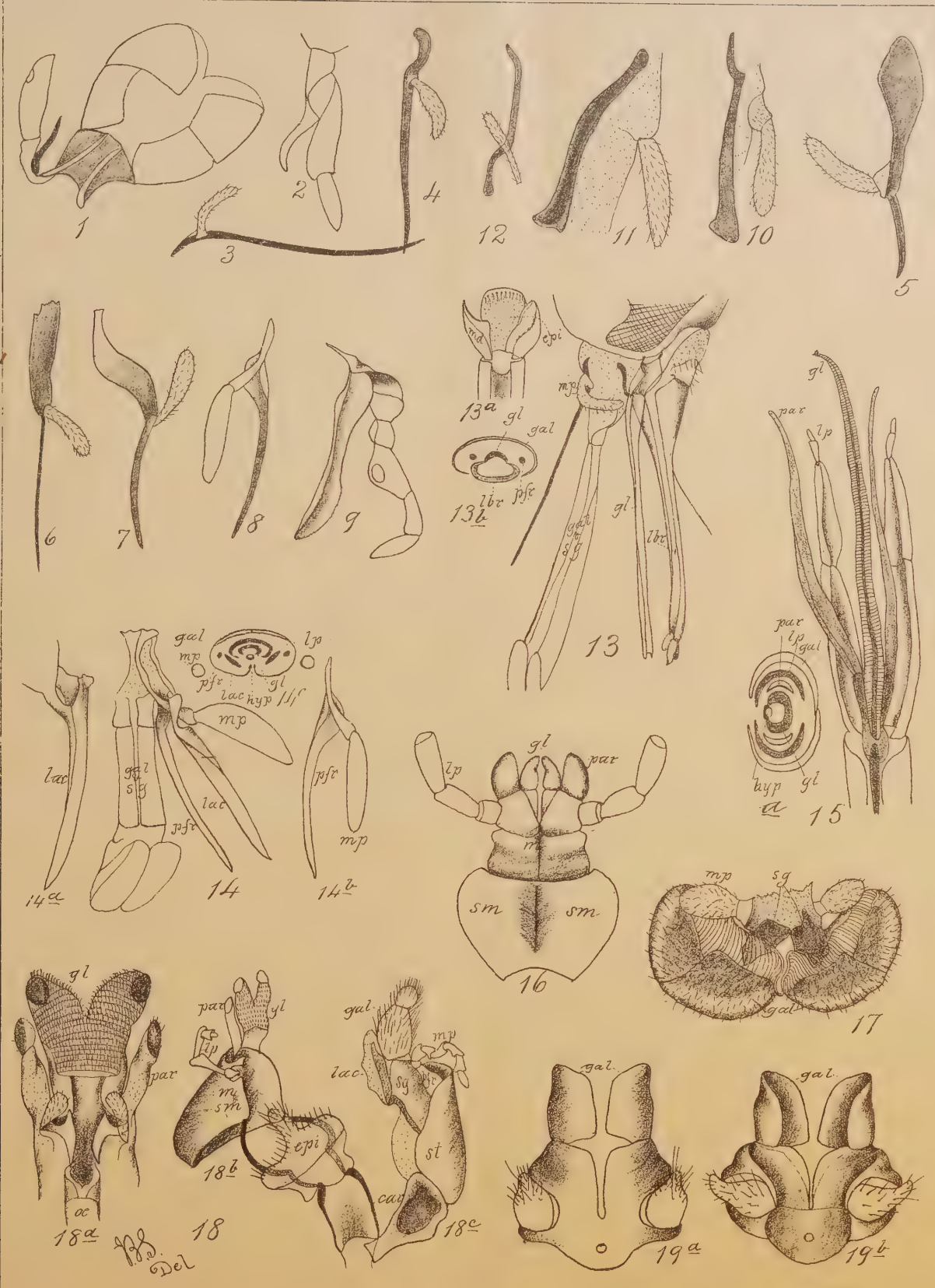
Figs. 10 to 12 inclusive were accidentally reversed in making up the plate.

- Fig. 13. Mouth parts of *Empis spectabilis*. 13^a, elongated head structure at tip, showing mandibles and epipharynx; 13^b, transverse section at middle of subgalea.
- Fig. 14. Mouth parts of *Chrysops vittatus* showing maxillary structures attached together. 14^a, the lacinia; 14^b, palpifer and palpus; 14^c, transverse section at middle of galea.
- Fig. 15. Labial structures of *Xenoglossa pruinosa*. *a*, transverse section at about middle.
- Fig. 16. Labial structures of *Periplaneta orientalis*.
- Fig. 17. Maxillary structures of *Hermetia mucens*.
- Fig. 18. Mouth structures of *Polistes metricus*. 18^a, ligula, paraglossa and mouth opening; 18^b, labium as a whole, with epipharynx attached; 18^c, maxilla.
- Fig. 19. Maxilla of *Olfersia*. 19^a, seen from front; 19^b, seen from behind or below.

Plate III.

- Fig. 1. Mouth structures of Asilidæ—*Laphria* sp. *a*, maxilla from front ; *b*, same from behind ; *c*, labium ; *d*, labrum ; *e*, transverse section of mouth at junction of galea and subgalea.
- Fig. 2. Mouth structures of *Ramphomyia longicauda*. *a*, the labium ; *b*, maxilla ; *c*, extension of front of head ; *d*, relation of this extension to the labium.
- Fig. 3. Galea of an *Andrena* allied to *vicina*.
- Fig. 4. Mouth parts of *Bittacus strigosus*. *a*, mandibles and labrum ; *b*, maxilla and labium ; *c*, mandibles and labrum—epipharynx of *Panorpa rufescens*.
- Fig. 5. Labial structures of *Eristalis tenax*. 5^a, transverse section at about middle ; 5^b, same at about tip.
- Fig. 6. Labial structure of *Bombus* sp. 6^a, transection at about middle ; 6^b, same made near tip.
- Fig. 7. Labium of *Harpalus calignosus*.
- Fig. 8. Maxilla of *Periplaneta orientalis*.
- Fig. 9. Maxilla of Perlid larva.
- Fig. 10. Epipharynx of *Eristalis tenax*.
- Fig. 11. Mouth parts of *Bibio* sp. *a*, maxilla from behind ; *b*, same in front ; *c*, transection made near the base.
- Fig. 12. Labium of *Bombus fervidus* ; the transections are lined to the portions referred to.
- Fig. 13. Labium of *Chrysops vittatus* ; the transections are lined to the parts referred to.
- Fig. 14. Labium of *Hermetia mucens*.
- Fig. 15. Maxillæ and labium of *Bombus*, showing the relation of the parts to each other.
- Fig. 16. Maxilla of *Sialis*.
- Fig. 17. Maxilla of *Hydrophilus* from upper and lower surface, redrawn from Comstock.
- Fig. 18. Maxilla and labium of *Pteromalus*, redrawn from Ashmead.
- Fig. 19. Maxilla of *Pronuba*, male.
- Fig. 20. Maxilla of *Nemognatha*.
- Fig. 21. Maxilla of *Pronuba*, female.
- Fig. 22. Mouth parts of *Locusta* from Kolbe. *i*, labrum ; *ii*, mandibles ; *iii*, maxillæ ; *iv*, labium.







ARTICLE III.

SOME EXPERIMENTS WITH THE SALIVA OF THE GILA MONSTER (HELODERMA SUSPECTUM).

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I. INTRODUCTION.

When, in 1651, Franciscus Hernandez published his *Historiæ animalium et mineralium Novæ Hispaniæ* he gave to Europe the first account of a curious reptile native to those far-western lands which the Spaniards had won beyond the sea. This was a large lizard, said to grow three feet long, thick-set, heavy-jawed, protected by an armor of wart-like bony plates, gaudily colored in orange and black—withal so repulsive that Wiegmann, nearly two hundred years later, christened it *Heloderma horridum*.

For many years, this name was applied to these lizards wherever found, but in 1869 Prof. Cope discovered that those which had been caught within the borders of the United States and Sonora differ in many details from their more southern relatives. He named the smaller, northern species *Heloderma suspectum*. It is this species which, because of its former abundance near the Gila river, in Arizona, has become popularly known under the name Gila Monster.

The Indians and Mexicans claimed for these lizards power to inflict a bite even more deadly than that of the rattlesnake, but, since they claimed like powers for other reptiles known to be quite innocent of venom, their evidence was of little value. It received some confirmation, however, when the herpetologists of Europe found that the teeth of the *Heloderma* bear grooves similar to those which in some poisonous snakes serve to introduce venom into the wound. Since this was discovered the question of the poisonous nature of the bite of the Gila Monster has attracted considerable attention and many opinions have been published.

In 1857, Dr. J. E. Gray, of the British Museum, wrote :

“ This lizard is said to be noxious, but the fact has not been distinctly proved.”

Seven years after this there appeared a popular account of the habits of the Mexican species (*H. horridum*), in which M. Sumichrast, after dwelling at some length upon the general habits of the animal, wrote :

“ In support of this pretended malignity, I have been told of a great number of cases in which ill effects were produced by the bite of the animal, or by eating its flesh in mistake for that of the Iguana. I wished to make some conclusive experiments on this point; but, unfortunately, all the specimens which I could procure during my stay in the countries inhabited by it were so much injured that it was impossible to do so. Without giving the least credit to the statements of the natives, I am not absolutely disinclined to believe that the viscous saliva which flows from the mouth of the animal in moments of excitement may be endowed with such acidity that, when introduced into the system, it might occasion inconveniences, the gravity of which, no doubt, has been exaggerated.”

Prof. Cope, in 1869, stated :

“ That though the lizards of this genus could not be proven to inflict a poisonous bite, yet that the salivary glands of the lower jaw were emptied by an efferent duct which issued at the basis of each tooth, and in such a way that the saliva would be conveyed into the wound by the deep groove of the crown.”

Six years later Dr. Yarrow said :

“ It is believed to be very poisonous, but such is not the case; for, although it will bite fiercely when irritated, the wound is neither painful nor dangerous. . . . The Pueblo Indians of this place said they were quite common, and were regarded by the Mexicans as poisonous; the poison being communicated by the breath as well as by the teeth. This has no foundation in fact.”

The same year, M. Bocourt published some notes which he had received from M. Sumichrast, who, having finally been able to make a few experiments, concludes :

“ Quoique ces expériences soient insuffisantes pour prouver que la morsure de l'Héloderme est véritablement venimeuse, elles me paraissent assez concluantes pour faire admettre qu'elle ne laisse pas de causer de très-rapides et profonds désordres dans l'économie des animaux qui en sont l'objet. . . .

“ Je ne doute pas que des expériences, faites avec des individus adultes et nouvellement pris, ne produisent des effets beaucoup plus terribles que ceux qu'ont pu occasionner la morsure d'un individu jeune et affaibli par une captivité de près de trois semaines.”

In 1882, several opinions were published on each side of the question. A Heloderma, which had been received at the Zoölogical Gardens in London, bit some small animals, and because these died several English writers—as Günther, Boulenger, and Fayrer—concluded that the Monster was poisonous, while some American authors have thought that death in these cases might have resulted from the mechanical injuries received. The *American Naturalist* noted that “ Dr. Irwin, U. S. A., experimented with the *H. suspectum* in Arizona, fifteen years ago, and concluded that it was harmless.”

Dr. R. W. Shufeldt had a personal encounter with an active Gila Monster, of which he wrote :

“ On the 18th inst., in the company of Prof. Gill of the [Smithsonian] Institution, I examined for the first time Dr. Burr's specimen, then in a cage in the herpetological room. It was in capital health, and at first I handled it with great care, holding it in my left hand examining special parts with my right. At the close of this examination I was about to return the fellow to his temporary quarters, when my left hand slipped slightly, and the now highly indignant and irritated *Heloderma* made a dart forward and seized my right thumb in his mouth, inflicting a severe lacerated wound, sinking the teeth in his upper maxilla to the very bone. He loosed his hold immediately and I replaced him in his cage, with far greater haste, perhaps, than I removed him from it.

“ By suction with my mouth, I drew not a little blood from the wound, but the bleeding soon ceased entirely, to be followed in a few moments by very severe shooting pains up my arm and down the corresponding side. The severity of these pains was so unexpected that, added to the nervous shock already experienced, no doubt, and a rapid swelling of the parts that now set in, caused me to become so faint as to fall, and Dr. Gill's study was reached with no little difficulty. The action of the skin was greatly increased and the perspiration flowed profusely. A small quantity of whiskey was administered. This is about a fair statement of the immediate symptoms; the same night the pain allowed of no rest, although the hand was kept in ice and laudanum, but the swelling was confined to this member alone, not passing beyond the wrist. Next morning this was considerably reduced, and further reduction was assisted by the use of a lead-water wash.

“ In a few days the wound healed kindly, and in all probability will leave no scar; all other symptoms subsided without treatment, beyond the wearing for about forty-eight hours so much of a kid glove as covered the parts involved.

. . . . “ Taking everything into consideration, we must believe the bite of *Heloderma suspectum* to be a harmless one beyond the ordinary symptoms that usually follow the bite of any irritated animal. I have seen, as perhaps all surgeons have, the most serious consequences follow the bite inflicted by an angry man, and several years ago the writer had his hand confined in a sling for many weeks from such a wound administered by the teeth of a common cat, the even tenor of whose life had been suddenly interrupted.”

Only a few months had passed after the publication of Dr. Shufeldt's article when there appeared an account of the first carefully conducted series of experiments with the saliva of the *Heloderma*. This was by Drs. S. Weir Mitchell and Edward T. Reichert, who conclude that :

“ The poison of *Heloderma* causes no local injury.

“ That it arrests the heart in diastole, and that the organ afterwards contracts slowly—possibly in rapid rigor mortis.

“ That the cardiac muscle loses its irritability to stimuli at the time it ceases to beat.

“ That the other muscles and the nerves respond readily to irritants.

“ That the spinal cord has its power annihilated abruptly, and refuses to respond to the most powerful electrical currents.

“ This interesting and virulent heart poison contrasts strongly with the venoms of serpents, since they give rise to local hemorrhages, and cause death chiefly through failure of the respiration, and not by the heart, unless given in overwhelming doses.”

For a time, it seemed that the experiments of Mitchell and Reichert had answered the question of the poisonous power of the *Heloderma* once and for all. But five years later, Dr. Yarrow, then Honorary Curator of the Department of Reptiles in the United States National Museum, performed some equally careful experiments upon rabbits and chickens. These, he says,

“ Would seem to show that a large amount of the *Heloderma* saliva can be inserted into the tissues without producing any harm, and it is still a mystery to the writer how Drs. Mitchell and Reichert and himself obtained entirely different results. Were it not for the well-known accuracy and carefulness of Dr. Mitchell, it might be supposed possibly that the hypodermic syringe used in his experiments contained a certain amount of *Crotalus*, or cobra venom, but under the circumstances such a hypothesis is entirely untenable.”

Notwithstanding Yarrow's results, Dr. Mitchell still held his original opinion in 1889.

The following year, Prof. Samuel Garman, of the Museum of Comparative Zoölogy of Harvard University, published an account of experiments in which he caused an active Gila Monster to bite the shaved legs of kittens without serious effect. He concludes that

“ The results of the experiments suggest danger for small animals, but little or none for larger ones. Large angle worms and insects seemed to die much more quickly when bitten than when cut to pieces with the scissors.”

Thus while in England the *Heloderma* was unanimously held to be venomous, Dr. Shufeldt, in 1891, summarized American opinion as follows :

“ Here in America the evidence would seem to be rapidly leading to the demonstration of the now entertained theory that the saliva of this heretofore much-dreaded reptile is possibly entirely innocuous.”

“ Thus the matter seems to stand at the present time—perhaps the vast majority of physicians who followed Drs. Mitchell and Reichert in their experiments fully believe to-day that the bite of a ‘ Gila Monster ’ will very often prove fatal even in the case of man; while, on the other hand, naturalists almost universally believe that the saliva of this saurian is hardly at all venomous, and then only under certain conditions.”

II. THE MOUTH FLUIDS.

In the winter of 1896–97 I began a series of experiments with the saliva of the Gila Monster, the results of which are given in the subsequent pages. My object was to answer the following questions :

- (a) Is the bite of the Gila Monster poisonous?

(b) If poison is present what are its physiological effects?

(c) What are the causes of such diversity of opinion?

My *Heloderma* was the sole survivor of eight or ten brought from Arizona in 1892 and, although seemingly fat and healthy, was not very active. It was of moderate size, being about eighteen inches long. The amount of saliva obtainable from it was so small that it could be gathered satisfactorily only by causing the reptile to bite absorbent paper wrapped around a piece of soft rubber and afterwards dissolving out the saliva in water. For this purpose filter paper was used.

It would not do to let the Monster bite the pigeons, because if this were done and the pigeons died the skeptics might justly claim that death was due to the mechanical injury inflicted by the powerful jaws, with their long, curved fangs, rather than to any poison having been inserted. Even when the *Heloderma*'s saliva solution was injected hypodermically and death could not have been occasioned by the severity of a wound there might be some doubt as to the effect of a quantity of water suddenly placed under the skin, or it might be claimed that some substance was present in the water or the paper used quite poisonous enough to cause a pigeon's death irrespective of any venom from the Monster. So samples of all the materials used had to be subjected to careful tests to show that they were harmless.*

MUCUS.

A greater or less quantity of thick mucus is present in the back part of the mouth of the Gila Monster. Some of this often adheres to the filter paper in stringy masses. It is entirely without poisonous properties and need not be mentioned again.

THE POISONOUS SALIVA.

The water solution of saliva when extracted from the paper is a slightly yellowish or opalescent liquid, often more or less stained with blood owing to injury to the gums. It is faintly alkaline, and ordinarily possesses a pungent and highly characteristic though not unpleasant odor. This odor becomes less and less noticeable when the Monster is caused to bite every day, but its strength seems to be no indication of the lethal power of the saliva. That the solution of saliva thus obtained contains a very powerful poison is shown in the following experiments:

EXPERIMENT I.—Nov. 11, 1896. The *Heloderma* was caused to bite on paper three times. The

*In order to test my materials, and some other things as well, the following preliminary experiments were performed, the first repeatedly:

EXPERIMENT.—A sample of filter paper was soaked in water, which was then injected subcutaneously in front of the wing of a pigeon. During two hours there was no effect, and the next day the bird was still well.

EXPERIMENT.—Mixed human saliva with an equal quantity of water and injected about twenty minims in wing of pigeon at 12.01 P.M. No effect. Next day well.

EXPERIMENT.—Mixed blood of horned toad (*Phrynosoma frontale* Van D.) with water and injected wing of pigeon. No effect.

water solution—about twelve minims—was then injected subcutaneously in front of the shoulder of a pigeon at 3.18 P.M. In three minutes the pigeon was no longer able to stand, and fell over on its side with eyes closed. At the end of the tenth minute the bird was unable to hold up its head when raised by its wings. During the eleventh minute respiration was in gasps, and at the end of the eleventh minute the pigeon was dead. [No local effects; heart beating regularly.]

EXPERIMENT II.—Nov. 12, 1896. Monster was caused to bite seven times during about as many minutes. Saliva then dissolved in about seventy minims of water, of which ten minims were injected under the skin in front of right shoulder of pigeon, at 11.24 A.M.

11.28. Pigeon barely able to walk.

11.29. Not able to walk.

11.30. Cannot stand; lies on side; eyes closed.

11.31. Head nods; respiration is forced.

11.32. Muscular straining; head drawn back between shoulders.

11.33–38. Respiration greatly forced; bill opens and shuts with each breath.

11.39. Violent contractions of caudal muscles.

11.40. Violent contractions of head and wings.

11.40 $\frac{1}{4}$. Head falls forward onto table.

11.40 $\frac{1}{2}$. Death.

No local effects; ventricles empty, auricles full of clots; blood almost black.

If these experiments leave any room to doubt that the bite of the Gila Monster is poisonous it is entirely removed by the results of a large number of experiments which I afterwards performed and in which death followed the injection of *Heloderma* saliva quite as certainly and almost as quickly as when rattlesnake venom is used.

It now became of interest to learn whether this powerful poison is affected by boiling or decay, or the presence of alcohol, etc.

The Effect of Boiling.—Two experiments were performed which show that the poisonous properties of the saliva are not injured by boiling. The solution becomes opalescent and, if boiling be prolonged, loses its odor or gives off one similar to that of boiled barley.

EXPERIMENT III.—Nov. 12, 1896. The *Heloderma* was caused to bite seven times during about as many minutes. Saliva then dissolved in about seventy minims of water. Ten minims of this solution, having been boiled a few seconds, were injected under the skin of the right shoulder of a pigeon, at 2.21 P.M. The temperature of the pigeon before injection was 104° F.

2.22. Sits down, but is able to stand when frightened.

2.26. Sits down.

2.27. Sits down immediately after being caused to stand, seems dizzy.

2.29. Lies on side; temperature 100°.

2.34. Cannot stand; temperature 98°.

2.36. Violent respiration; temperature 96°.

- 2.38. Violent respiration; temperature 98°.
- 2.39. Violent respiration; temperature 100°.
- 2.42½. Violent respiration; temperature 101½°.
- 2.45. Violent respiration; temperature 100°.
- 2.48. Respirations about 108 per minute; temperature 99°.
- 2.50. Temperature 100°.
- 2.53. Respiration more labored; temperature 99°.
- 2.54. Temperature 98°.
- 2.55. Temperature 97°.
- 2.56–57. Temperature 93°; respiration short and forced, 39 per minute.
- 2.58. Wheezing; vomits.
- 2.58½. No motion except quivering of wings; temperature 90°.
- 2.59. Wings and tail flapped twice.
- 3.00. Dead.

No local effect; small clot of blood in base of right lung; ventricles full of black clots; auricles beating; arteries empty; veins dilated with blood.

This experiment would seem to show that the action of the poison is slightly delayed by boiling. Experiment IV shows that such is not the case.

EXPERIMENT IV.—Nov. 14, 1896. Ten minims of the solution used in experiments II and III were boiled about five minutes on Nov. 12, and again Nov. 13 and 14, and then were injected under the skin of a pigeon's wing at 3.30 P.M.

- 3.34. Respirations 32 per minute.
- 3.37. Staggers about with peculiar circular motion.
- 3.39–40. Respirations 48, becoming constantly more forced, so that at end of minute tail moves up and down.
- 3.42. Cannot stand.
- 3.44–45. Respirations 49.
- 3.46. Falls on side.
- 3.47. Head nods; pupil seems slightly dilated.
- 3.52. Respirations 47, irregular.
- 3.53. Bill begins to open and shut.
- 3.54. Convulsive action of wings and head, head drawn under to breast.
- 3.55. Death.

The Effect of Decay.—When a solution of saliva is allowed to stand for a few days it soon begins to decay, and this process continues until a strong odor of putrescence is given off and a muddy sediment appears at the bottom of the liquid. After this had occurred, very large doses of the solution were injected into pigeons without producing the slightest ill-effect. Decay, then, appears to destroy the lethal power of the saliva, but my experiments are not absolutely conclusive because the solution was not tested while fresh.

EXPERIMENT V.—Saliva of several bites was collected, November 14, and dissolved in about ten minims of water per bite. November 16 there was a marked odor of decay. November 23 the odor of putrescence was very strong and the liquid appeared muddy with a slight sediment. At 2.31 P.M., ten minims were injected under the skin in axilla of pigeon whose temperature at 2.29 (when frightened) was 106°.

- 2.35–36. Respirations 33.
- 2.40. Temperature 105°.
- 2.44–45. Respirations 32.
- 3.09. Temperature 104°.
- 3.10–11. Respirations 32.
- 3.28–29. Respirations 32.
- 3.31. Temperature 104°. Repeated injection.
- 3.33–34. Respirations 34.
- 3.55–56. Respirations 32.
- 4.21–22. Respirations 33.
- November 24, etc. Still perfectly well.

EXPERIMENT VI.—December 1, 1896. Injected forty minims of solution used in experiment V under skin of legs and wing of pigeon at 12.45 P.M.

- 4.30. Still no effect.
- December 2. Well.

The Effect of Drying.—That drying does not affect the power of the venom was shown by the following experiment, although the dose was too small to cause death.

EXPERIMENT VII.—December 1, 1896. A small quantity of the solution used in experiments II, III and IV, having been dried, was redissolved in water and injected subcutaneously in a pigeon at 3.40 P.M.

- 4.10. Respiration slightly forced.
- 4.30. Cannot walk well.
- 4.45. Very “tame;” respiration forced.
- December 2. Pigeon recovered.

The Effect of Alcohol.—When alcohol is added to a water solution of saliva, the solution becomes opalescent, as when boiled. This change in color is probably due to the formation of a finely divided albuminous coagulate. It is not removed by filtration through paper. Alcohol does not influence the action of the venom.

EXPERIMENT VIII.—About twenty minims of the solution used in experiments II, III, IV and VII was mixed with an equal quantity of ninety-five per cent. alcohol, November 14. About half of this had evaporated when ten minims of the remainder were mixed with ten of water and thrown down the throat of a pigeon at 11.25 A.M., November 18.

- 11.46. Seems well.
- 2.15 P.M. No effect.

- 2.26. Injected the other ten minims in left axilla.
- 2.29. Shows uneasiness of left wing and cannot always control it.
- 2.29½. Sits; cannot walk.
- 2.30. Pupils contracted; cannot stand.
- 2.31. Lies on side; respiration convulsive.
- 2.32. Respiration still more labored.
- 2.33. Seems unable to feel pinching of legs.
- 2.37. Rate of breathing very greatly increased.
- 2.38-39. Respirations 62.
- 2.40-41. Respirations 84.
- 2.43-44. Respirations 64.
- 2.45-46. Respirations 53.
- 2.46-47. No respiration; convulsions.
- 2.48. Death.

Auricles beating; ventricles still; blood black, clotted; auricles and veins full; ventricles and arteries empty; slight extravasation in coat of small intestine near head of pancreas; no local effect.

Ninety-five per cent. alcohol when added to undiluted saliva does not injure its poisonous properties, nor does the alcohol act as a solvent of the venom, although its solubility in water is unaffected.

EXPERIMENT IX.—November 23, 1896.

a. Filter paper containing saliva was washed in about one ounce of alcohol for about twenty hours. The alcohol was then poured into an open dish. As soon as evaporation began a thin white scum appeared on the surface of the alcohol, but did not increase much as evaporation proceeded to dryness. This scum was not soluble in water, even after the addition of salt (NaCl). Placed under the skin of a pigeon, it produced no effect.

b. The alcohol-washed paper was soaked during a few minutes in sixty minims of water. Twenty minims of this water were injected under the skin of each wing of a pigeon at 3.25 P.M., November 24. Half an hour later twenty minims were injected into the left leg.

- 4.07. Pigeon sits down.
- 4.12-13. Respirations 45.
- 4.15-21. Stands on right leg only.
- 4.22-23. Respirations 54.
- 4.23-24. Respirations 49.
- 4.25. Temperature still normal, 102°
- 4.35. Temperature 99°.
- 4.39-40. Respirations 48.
- 4.42. Temperature 98°.
- 4.44-46. Respirations 35 per minute.
- 4.47. Temperature 96°. Slides along on breast when trying to walk.
- 4.47-48. Respirations 44, very weak.

- 4.52. Temperature 96°.
- 4.53-54. Respirations 44.
- 4.56-57. Respirations 31.
- 4.58. Temperature 96°.
- 5.00-01. Respiration, wheezing pants.
- 5.01-02. Respirations, wheezing pants, 21.
- 5.02. Temperature 96°. Death without struggles.

The Effect of Glycerine.—Glycerine seems to dissolve the poison and to partly destroy its effectiveness, though this seeming injury may be due to the slowness with which the glycerine is absorbed, preventing the poison from reaching the circulation rapidly enough to result fatally.

EXPERIMENT X.—Paper containing saliva of four bites was placed in about forty minims of glycerine and left for some hours. The glycerine, having been extracted, was injected in the breast muscles of a pigeon at 12.10 P.M., December 4, 1896.

1.00. Still no effect.

5.15. Still no effect.

December 5. Well, but with yellowish-white swelling on breast.

December 17. Well, but breast muscles sloughing. Used in experiment XII.

EXPERIMENT XI.—December 4, 1896. Since it was quite possible that the poison had not been dissolved by the glycerine, the paper used in the last experiment was well washed in alcohol to remove glycerine, and then, after the alcohol had been removed by pressure and evaporation, was placed in water (thirty minims). This water was injected into a pigeon at 3.15 P.M.

3.30. No signs of poison.

5.15. No effect yet.

December 5. Well.

December 8. Well.

EXPERIMENT XII.—December 17. Saliva of the lower jaw from about three bites was collected and divided into two parts, one slightly larger than the other. The larger part was then soaked in glycerine, a little more than one-half of which was afterward injected in leg of pigeon used in experiment X.

4.35 P.M. Injected subcutaneously.

5.30. Seems slightly drowsy; otherwise well.

December 18. Found dead.*

EXPERIMENT XIII.—December 17, 1896. To test the power of the saliva used in experiment XII the smaller portion of the saliva-soaked paper was placed in a small quantity of water, and one-half of the resulting solution injected in the breast muscles of a pigeon, December 18.

4.07. Injected.

4.30. Bird sitting; staggers when raised.

* Death may have been due to the rather extensive sloughing of the pectoral muscles, but that this was the case does not seem probable.

- 4.31-32. Respiration still normal, *i. e.*, 35.
 4.35. Can still stand.
 4.36-37. Respirations 30.
 4.39-40. Respirations 31.
 4.46-47. Respirations 29; sits with eyes closed.
 4.53. Does not notice loud noises, as stamping on floor; cannot stand.
 4.55-56. Respirations 31.
 4.58. Head moves from side to side, slightly.
 4.59-5.00. Respirations 30.
 5.03-04. Respirations 34, slightly forced.
 5.09-10. Respirations 34, slightly forced.
 5.13-14. Respirations 43, a little more forced; head nodding.
 5.15-16. Respirations 36, nearly normal.
 5.18-19. Respirations 32, slightly forced.
 5.21-22. Respirations 50, much forced.
 5.23-24. Respirations 32, convulsive.
 5.24-25. Respirations 23, convulsive.
 5.25½. Raises tail and flaps wings.
 5.26-27. Respirations 13, weak.
 5.28. Heart still beating strongly and regularly.
 5.30. Death.

Heart irritable and nerves of pectoral muscles, etc., likewise; blood very dark, semi-liquid, coagulating quickly; no local effects.

THE HARMLESS SALIVA.

There is, then, in the saliva of the Gila Monster a very powerful poison which may be subjected to very rough treatment without impairing its lethal vigor. *This poison is present in the saliva of one jaw only.* If, when collecting the mouth fluids, the rubber be properly placed between two layers of paper, the saliva from each jaw may be readily obtained unmixed with that of the other. When thus obtained and dissolved in water, the saliva of the upper jaw is a yellowish liquid, usually more or less tinted with blood, slightly alkaline, without any odor, and absolutely harmless at the very time when the lower jaw is flooded with deadly venom. The quantity of saliva which may be collected from the upper jaw at any one time is only a little less than is obtainable from the lower; but in one case all of the saliva from the upper jaw was injected into a pigeon without causing the slightest ill effect, while one-fifth of that obtained at the same time from the lower jaw caused death in fifty-two minutes.

The following experiments are quite numerous enough to show beyond doubt the difference in effect between the two kinds of saliva.

EXPERIMENT XIV.—November 24, 1896. Saliva of upper jaw from four bites was dissolved in water one-half of which (ten minims) was injected into a pigeon at 11.40 A.M.

3.08. Still no effect; repeated injection.

5.40. Still no effect.

November 25. Well.

EXPERIMENT XV.—November 24, 1896. Same as last experiment, but with saliva of lower jaw in another pigeon.

12.15 P.M. Temperature 104°.

12.17. Injected.

12.20–21. Respirations 31.

12.27–28. Respirations 31.

12.35. Temperature 100°.

12.36–37. Very “tame.” Respirations 38.

12.38. Sways backward and forward.

12.39–40. Respirations 32.

12.42. Temperature 98°.

12.47–48. Respirations 30.

12.50. Very drowsy. Temperature 97°.

12.54–55. Respirations 34, irregular.

1.03–04. Respirations 28, labored.

1.06. Temperature 95°. Can still stagger when placed on feet.

1.09–10. Respirations 38, very irregular.

1.11. Temperature 96°.

1.16. Temperature 95°.

1.17–18. Respirations 42, greatly labored.

1.23. Temperature 95°.

1.24–25. Respirations 46, bill opening and shutting. Can still walk slowly.

1.28–29. Respirations 55.

1.30. Temperature 96°.

1.33–34. Respirations 52. Can barely walk.

1.36. Temperature 96°.

1.37. Cannot walk.

1.37–38. Respirations 54.

1.46. Temperature 94°.

1.47–48. Respirations 49, head nods.

1.53. Temperature 94°.

1.54. No respiration.

1.55. Temperature 93°.

1.56. Death with convulsions.

EXPERIMENT XVI.—November 25, 1896. At 2.15 P.M., injected a pigeon with all of solution of saliva of upper jaw from four bites.

2.30. Still no effect.

2.40. Still no effect.

3.07. Still no effect.

5.05. Still no effect.

November 26. Well.

EXPERIMENT XVII.—November 25, 1896. Injected one-half of the solution of lower-jaw saliva from same bites as last experiment.

3.02-03. Respirations 37; temperature 104° .

3.06. Injected as above stated.

3.14. Temperature 102° .

3.23-24. Respirations 38.

3.27. Very "tame," temperature 98° .

3.28. Cannot stand.

3.28 $\frac{1}{2}$ -29 $\frac{1}{2}$. Respirations 53.

3.30. Temperature 98° .

3.32-33. Respirations 45.

3.33. Temperature 98° .

3.37. Temperature 98° .

3.38-39. Respirations 45.

3.40. Temperature 96° .

3.40-41. Respirations 45.

3.51. Temperature 94° .

3.53-54. Respirations 43.

3.56. Temperature 94° .

3.58-59. Respirations 45.

4.07. Temperature 93° .

4.15-16. Respirations 51.

4.21. Temperature 93° .

4.27-28. Respirations 26.

4.29. No respiration.

4.30. Death.

Heart (auricles and ventricles) beating strongly when exposed at 4.31 and until 4.36; blood in veins; arteries and ventricles empty; no local effect.

EXPERIMENT XVIII.—November 28, 1896. Injected all of solution of saliva from upper jaw, in pigeon, at 11.55. No effect.

EXPERIMENT XIX.—November 28, 1896. Injected all of solution of saliva from lower jaw (same bites as last experiment) in pigeon at 12.15 P.M.

12.19. Tips forward on legs, therefore cannot stand still.

12.20. Seems dizzy.

12.20 $\frac{1}{4}$. Sits.

12.22. Can walk well.

- 12.24. Very "tame;" hardly able to walk.
- 12.27. Can stagger with help of wings.
- 12.34. Respiration terribly labored, loud, wheezing pants, about 28 per minute.
- 12.39. Head drawn far back; still panting.
- 12.40. Still panting, but more slowly and weakly, 24 per minute.
- 12.41. Struggles, lies on side with head on floor.
- 12.42. Respiration practically stops.
- 12.42 $\frac{1}{2}$. Dead.

EXPERIMENT XX.—December 1, 1896. Injected solution of saliva of upper jaw from two bites, at 12.30 P.M.

- 1.30. Pigeon has shown no signs of poisoning.
- 3.30. Still no effect.
- 4.30. Still no effect.
- 5.00. Still no effect.
- December 2. Well.

EXPERIMENT XXI. Injected solution of saliva of lower jaw from same two bites (experiment XX) at 2.25 P.M., December 1, 1896.

- 3.25. Totters; lies down when set on feet.
- 4.00. Totters, leaning forward.
- 4.10. Can still totter.
- 4.20. Cannot rise or stagger.
- 4.30. Muscles all tense; bill opens and shuts.
- 4.30 $\frac{1}{2}$. Respiration ceases.
- 4.31. Death.

EXPERIMENT XXII.—December 2, 1896. All of the solution of saliva of the upper jaw from three bites was injected under the skin of the wing of a brown pigeon at 3.05 P.M. without any effect.

EXPERIMENT XXIII.—December 2, 1896. Two-fifths of the solution of lower-jaw saliva from the same three bites as last experiment were injected under the skin of wing of a pigeon at 3.15 P.M.

- 3.25. No effect yet.
- 3.28. Staggers slightly; sits immediately; respiration slightly forced.
- 3.32. Respiration very rapid—forced.
- 3.36. Respiration very slow but labored.
- 3.40. "Skates" on breast when trying to walk.
- 3.43. Convulsive quivering of wings.
- 3.44–45. Convulsive quivering of wings.
- 3.45. Lies stretched out on floor; convulsive respiration; wheezing with each breath.
- 3.48. No respiration.
- 3.48 $\frac{1}{2}$. Death.

EXPERIMENT XXIV.—December 2, 1896. Two-fifths of the solution used in the last experiment (XXIII) were injected in the breast muscles of a slate-colored pigeon at 3.16 P.M.

- 3.25. Barely able to walk.
- 3.26. Not able to stand; respiration forced.
- 3.28. Lies on side with head drawn back.
- 3.34. Respiration very rapid and convulsive, bill opening and shutting; head twisted on side.
- 3.39. Respiration ceases.
- 3.39½. Apparently dead.
- 3.40. Heart still beating.

EXPERIMENT XXV.—December 2, 1896. One-fifth of solution used in experiments XXIII and XXIV was injected in a gray pigeon at 3.20 P.M.

- 3.25. Respiration deeper.
- 3.42–43. Respiration *very* rapid and shallow, 148 per minute.
- 3.51–52. Respirations 167; can still walk, but sits immediately.
- 3.58–59. Respirations 168.
- 4.02. Cannot stand.
- 4.04. Slight trembling.
- 4.05–06. Respirations 149.
- 4.08. Head drawn back; bill opens and shuts.
- 4.09–10. Respirations 62.
- 4.10. Slight general contractions of muscles.
- 4.11¼–11½. Respirations 4.
- 4.11½–12. No respiration.
- 4.12. Death.

EXPERIMENT XXVI.—December 8, 1896. Solution of upper-jaw saliva from one bite injected in breast of a gray pigeon at 3.08 P.M. without effect.

EXPERIMENT XXVII.—December 8, 1896. One-half of solution of lower-jaw saliva, same bite as experiment XXVI, was injected in breast muscles of a gray pigeon at 3.16 P.M.

- 3.26. Pigeon very quiet.
- 4.00 Drowsy.
- December 9. Well.
- December 18. Well.

THE SOURCES OF SALIVA.

We have seen that two very different fluids are present in the mouth of the Heloderma; the one—from the lower jaw—capable of causing profound disorder when introduced into the circulation of pigeons, the other—from the upper jaw—producing no more effect than so much water. What are the sources of these fluids?

In *Heloderma suspectum*, there are two large glands, one on each side of the anterior part of the lower jaw between the skin and the bone. When one of these glands has been freed from its outer sheath it is found to be not a single gland but a series of three or four glands, each perfectly distinct from the others and emptied by a separate duct. These glands increase in size posteriorly, so that the last is very much larger than the first. They vary in number because of the occasional union of the first and second glands, or the presence, posteriorly, of a small, isolated, ductless portion. Their ducts open between the lower lip and gum, as described by Stewart. It is shown later on that these are the venom-producing glands.

No glands have yet been described as existing in the upper jaw; indeed there seems to be no room there for a well-developed gland. Nevertheless, paper which comes in contact with the upper jaw during the bite collects almost as much fluid as is obtained from the lower jaw. This, however, is true only when the paper is bitten a very few times. The saliva of the upper jaw is exhausted much more quickly than that of the lower. This fact, taken in connection with the absence of known glands, might lead one to suspect that the upper jaw receives its saliva from the lower and holds it in the complicated folds of its gums. This might perhaps be true if one or more segments of the sublabial glands secreted a harmless fluid, but the following experiments show that all are specialized for the production of venom. I believe that the harmless saliva is secreted by minute glands which lack of material has prevented me from finding—that it is in fact the ordinary buccal liquid of lizards. That it is present in the lower jaw as well as in the upper would seem to be shown by the fact that the fluids of both jaws are decidedly alkaline, while a solution of the poison gland itself is quite neutral.

The following experiments were performed to show that each part of the sublabial glands is devoted to the production of venom:

EXPERIMENT XXVIII.—January 5, 1897. Soaked the first portion of the right sublabial gland in water and injected the resulting solution (three minims) into the breast muscles of a small finch, at 12.26 P.M.

12.28. Respiration forced; eyes closed.

12.29. Respiration greatly forced.

12.31. Flutters.

12.31½. Convulsions and death.

12.33. Heart beating weakly; blood dark but lightens quickly.

EXPERIMENT XXIX.—January 5, 1897. Soaked the second portion of the right sublabial gland in water and injected solution (four minims) into breast muscles of a small finch, at 12.00 M.

12.04. Eye nearly closed; respiration normal.

12.05. Respiration slightly forced.

- 12.05½. Bill begins to open and shut.
12.07. Respiration greatly labored.
12.08. Convulsions followed by death.
12.10. Heart still beating; blood dark, lightens slowly.

EXPERIMENT XXX. Treated the third portion of right sublabial gland as the first and second were treated in experiments XXVIII and XXIX, and injected four minims into a small finch at 11.34 A.M.

- 11.35. Wheezes; sitting down; eyes closed; tail moving up and down with each breath.
11.36. Same, but bill opening and shutting.
11.37. Does not open eyes when handled.
11.37½. Respiration very short and jerky.
11.38. Respiration ceases, followed by convulsions and death.
11.41. Heart still beating, empty; blood dark brown, reddening very slowly.

EXPERIMENT XXXI.—January 5, 1897. Injected four minims of solution of fourth portion of right gland into a small finch, at 11.07½ A.M.

- 11.08½. Unable to stand erect; head drooping.
11.09. Respiration labored.
11.09½. Respiration greatly labored.
11.10. Bill opens and shuts.
11.11. Bird falls on side.
11.12½. Respiration in gasps.
11.13. Convulsions and death.
Heart responds to mechanical stimuli; blood black but becoming red on exposure.

EXPERIMENT XXXII. Injected five minims solution of first portion of left sublabial gland into a small finch, at 2.41 P.M.

- 2.42. Eyes closed.
2.45. Respiration labored; bird leaning on side.
2.46. Almost unconscious; bill opening and shutting.
2.47. Convulsions.
2.47¼. Death.

EXPERIMENT XXXIII. Injected six minims of water into the breast muscles of a small finch without effect.

III. THE PHYSIOLOGICAL ACTION OF HELODERMA POISON.

When a pigeon has received an injection of Gila Monster saliva it at first shows no ill effects, and feeds or fights with its fellows as before. Soon, however, it begins to wink very frequently, and ceases to show interest in anything about it. It stands thus for a

longer or shorter time and then sits down. If now it be frightened into attempting to walk, it appears dizzy and staggers about, or, if unable to stand, slides along on its breast. If not caused to arise, it never does so of its own accord, but becomes more and more drowsy and sits with eyes closed. The rate of respiration now becomes very rapid for a time, but soon the breaths are shallower and then gradually fewer and fewer.* The legs become more or less paralyzed, but the wings retain their power, although the coördination of their motions sometimes is destroyed. The temperature falls as the respiration becomes slower. The bird rolls over on its side. The head is drawn down over the back. Respiration becomes nothing more than a series of wheezing gasps, with each of which the bill opens and shuts. The head falls forward to the floor. The pigeon is unconscious. Breathing ceases. There may be slight convulsions followed by death, or death may come quietly.

If the pigeon now be opened, it is found that the blood is very dark—often almost black instead of red or blue. The heart either is beating or responds readily to mechanical stimuli. The arteries and usually the ventricles of the heart are empty, while the veins and auricles are full of blood which usually is more or less clotted. There is no trace of discoloration about the point of injection, nor is the slightest extravasation of blood to be found in any of the organs.

With all these facts in view, it is very evident that death is due to asphyxiation; to the failure of the blood to provide the various tissues of the body with the oxygen necessary for their welfare. But, although we may say that death is due to asphyxiation, we have not really answered our question, for there are several ways in which this failure on the part of the blood might be brought about:

1. If the poison acted upon the nerve centres which control the movements of respiration in such a way as to interfere with the action of the lungs, the blood would be unable to procure its usual supply of air. We have seen that there is a very decided disturbance of the respiratory function.† It may, perhaps, be due to direct nerve-poisoning; but I am inclined to believe that it is entirely a secondary phenomenon.

2. If the poison caused a breaking down of the capillaries of the lungs—such as Martin‡ claims to have found in certain cases of death from the venom of the Australian black snake—the same effect would be produced, but there appears to be no such change.

3. If the action of the heart became gradually weaker—as Mitchell and Reichert have stated of their experiments—the flow of blood would be diminished and the tissues

*This is normally true, but respiration sometimes stops suddenly, even nearly at the time when it is most rapid.

†The table upon the opposite page shows the effect upon the number of respirations and the temperature.

‡Martin, *Jour. and Proc. Royal Soc. N. S. Wales*, XXIX, 1895, 146-276.

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[illegible]

would not receive their normal amount of oxygen. In all my experiments the heart continued to beat regularly long after respiration had ceased, so that this cannot have been the cause of death.

4. If the poison acted upon the blood in such a way as to destroy its power to carry oxygen—as Cunningham * says is true of cobra venom—or,

5, if the poison caused the formation of clots in the veins, thus stopping the flow of blood—as Martin tells us the venom of the Australian black snake does—in either case the effect would be the same as if the action of the lungs were to cease.

The sudden death of my Gila Monster prevented me from testing these possible causes of asphyxiation from its poison, but I shall not be surprised if it be found that in one or both of them exists the explanation of the phenomena exhibited.

But perhaps I should limit this statement somewhat, for Mitchell and Reichert state very positively of their experiments that death was occasioned by the action of the poison upon the heart. Here is an apparent contradiction of my results, and by the highest American authority upon reptile poisons; but the seeming contradiction disappears, perhaps, when we recall that Dr. Mitchell's Gila Monster saliva was less dilute than mine, and that it is known of some serpent poisons that "with higher concentration of venom the heart is the more rapidly affected, but the continuous operation of the poison in small concentration more quickly affects the respiratory" system.

IV. SOME CAUSES OF DIVERSITY OF OPINION.

We have now reached our last question: Why has the bite of the Gila Monster so often been considered harmless?

Several reasons must, I think, already have suggested themselves. Dr. Shufeldt, it will be remembered, was severely bitten on the thumb, and concluded that the bite of the Gila Monster is no more poisonous than that of other angry animals; for example, a cat. But Dr. Shufeldt expressly states that the wound was made by the upper teeth penetrating to the bone, and we have already seen that the saliva of the upper jaw is harmless at all times, the venom being confined to the lower jaw.† So it well may be that Dr. Shufeldt owes his life to the circumstance that the injury to his thumb was inflicted by the upper instead of the lower teeth of the Monster.

This same fact will account for the experiences of other authors who have thought the bite of this reptile harmless, but there are other reasons for the occasional failure of the *Heloderma* to inflict a deadly wound. The teeth, although sharp and long, are very weakly fastened to the jaws, and often so many of them have been broken out that the

* Cunningham, *Sci. Mem. Med. Officers Army India*, IX, 1895, pp. 1-54.

† It would be interesting to know why the teeth of the upper jaw are grooved.

Monster is unable to inflict a wound at all. Even if the teeth are in working order the chances of the poison finding its way into the wound are very few, for the teeth are not directly connected with the poison glands, and the latter are below the fangs instead of above as in poisonous snakes. The poison simply flows out onto the gums below the teeth, and, to be effective, has to be forced *up* into the wound. Unless the flow of saliva be abundant and the teeth all present and forced into the bitten flesh so deeply as to press it down upon the poison ducts where they open between the lip and the gum, it is difficult to see how even the smallest quantity of poison could enter the wound, even though the teeth are grooved to afford it a passage. The strange thing, then, is not that bitten animals should sometimes survive, but that they should sometimes die.

Nevertheless, small animals often do die from the bite of this, the only poisonous lizard, and we must believe that a venom which can kill a pigeon in seven minutes and a rabbit in less than two might easily under favorable circumstances cause a wound to prove fatal even to man—a belief which is rendered far from improbable by the extraordinary virulence of the poison and the lizard's habit of holding like a bulldog to whatever it bites.

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ARTICLE IV.

RESULTS OF RECENT RESEARCHES ON THE EVOLUTION OF THE STELLAR SYSTEMS.

(Plates IV and V.)

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It is now two hundred and eleven years since Newton published the *Principia*, embodying his grand generalization of the law of gravitation, and the proof of this law for the most obvious and fundamental phenomena of the solar system. Geometers have since been occupied with the development and extension of the principle discovered by the illustrious Newton, and have finally explained with almost entire satisfaction the motions and attractions of the planets, satellites, comets, and other bodies which revolve about the sun. This great development can hardly fail to excite the admiration of those who contemplate the history of scientific progress, and must be accounted one of the most noble and enduring monuments of the human mind. So sublime an achievement has required the combined labors of a long series of men of transcendent mathematical and mechanical genius, each building upon the foundation laid by his predecessors. Though many distinguished geometers have borne an honorable part in this remarkable development of Physical Astronomy, it will not be inappropriate to point out the great credit for the perfection of the Newtonian theory due to Clairaut and Euler, Lagrange and Laplace, Gauss and Hansen, Adams and Leverrier. Among living investigators in mathematical astronomy the names of Hill and Newcomb, Darwin and Poincaré occupy the foremost place. These great men have brought the mechanics of the heavens to so high a state of perfection that in almost every case we may now predict the heavenly motions as accurately as we can observe them. In view of the rapid perfection of telescopes and other instruments of precision, this achievement, from the intricacy of the analysis required in the problem, and the abstruseness of the methods used in the reduction of

observations, must be ranked as incomparably the most profound yet attained in any branch of Physical Science.

Notwithstanding these splendid triumphs of the science of Celestial Mechanics, an even greater and more recondite work remains to be done in a closely related field. This is the investigation of the origin and cosmical history of the planetary and other systems observed in the immensity of space. Even if some credit for pioneer work on this problem be assigned to Kant, or, more remote still, to the Greeks of the pre-Socratic age, it yet remains true that Laplace is the real discoverer to whom we are indebted for the first ideas which proved fruitful for the advancement of science. About a century ago this great geometer outlined for the solar system the celebrated Nebular Hypothesis, upon which nearly all subsequent investigation has been based, and which has since been substantially confirmed, though but very little modified until within the last twenty-five years. Passing over as irrelative in the present discussion the early work of Herschel and Rosse, Helmholtz and Kelvin, Newcomb and Lane, we come down to the modifications introduced by Darwin about 1880.

In establishing the theory of gravitation, Newton assigned also the true cause of the tides of the seas, though his explanation carried with it all the defects of the equilibrium theory. More than a century passed before the dynamical character of the problem of the oceanic tidal oscillations was clearly perceived, when Laplace developed and applied the true theory with all the penetration characteristic of that great mathematician. Yet in spite of the profundity which marks his treatment of the tides of the oceans, it seems never to have occurred to him, or at least he made no record of the fact, that the attraction of the moon necessarily produces tides in the body of, as well as in the aqueous layers covering, the earth. We need not be surprised at this omission on the part of Laplace and those who followed him, if we recall that for many years after the perfection of Analytical Mechanics by D'Alembert and Lagrange, the subject was treated wholly from the point of view of material particles, and the resulting system was what is now called Rigid Dynamics. Little attention was bestowed upon the theory of fluid motion, partly because of its intricacy, and partly because there were no obvious applications of the results except in the case of the tides, already treated by Laplace with great penetration and extreme generality. As mathematicians since the time of Newton had been occupied chiefly with the development of the theory of planetary perturbations along the line of rigid dynamics, it did not occur to them that they were building on a false premise, that in reality the heavenly bodies so far as known are not solid, but fluid, though Laplace with his usual sagacity had long foreseen that in the case of our planets the nuclei are covered with fluid layers held in equilibrium by the pressure and attraction of their parts. His grand treatment in the *Mécanique Céleste* recognizes the fluidity of

the envelopes of the planets, and exhaustively examines the oscillations that will arise therein. Nor did he fail to consider fully the deviations from spherical form and the probable laws of density for the layers which compose the bodies of the planets.

The effect of so monumental a work as the *Mécanique Céleste* was twofold: on the one hand it brought Physical Astronomy to an unexpected state of perfection, while on the other it produced the impression on the less creative minds that there were no great problems untouched by the master-mind of Laplace. His work had indeed well-nigh exhausted the theory of Celestial Mechanics, so far as it could be built upon the assumptions of rigid dynamics; at least subsequent work has been for the most part little more than refinement or perfection of the methods and processes given in the *Mécanique Céleste*. The work of Laplace was designed for the solar system, and the idea that the universe is really composed of fluid bodies, self-luminous stars and nebulae in space, seems never to have occurred to him, or he would have foreseen that however adequate Rigid Dynamics may be for effecting a first approximation, the true theories of ultimate Celestial Mechanics must be founded upon the laws of viscous fluids in motion. So great is the influence of tradition that it is difficult for us to realize fully that the stars and nebulae are viscous fluids, self-luminous liquid or gaseous masses, and that even in the solar system the bodies are all fluids of various viscosities. This new point of view respecting the actual facts of the universe has brought about an important modification in the nebular hypothesis and in the ultimate theories of Celestial Mechanics, of which we shall now give some account.

About 1875, G. H. Darwin, who had qualified himself for the Law and been called to the Bar, on account of ill-health, abandoned his profession to undertake for Lord Kelvin some scientific work, which among other things included the reduction of a great mass of Indian tide observations with a view of throwing light upon the problem of the rigidity of the earth. This work, besides leading Lord Kelvin to the celebrated conclusion that the earth as a whole is "probably more rigid than steel, but not quite so rigid as glass," was the occasion* of the younger Darwin developing the theory of bodily tides, or the theory of the tides which would arise in the earth on supposition that it is not rigid as at present, but a viscous fluid, as it must have been, according to Laplace, at some past age. While some allusions to bodily tides can be found in scientific literature as far back as Kant, and especially in the papers of Delaunay on the secular acceleration of the moon's

* In the *Atlantic Monthly*, for April, 1898, Prof. Darwin remarks: "It was very natural that Mr. See should find in certain tidal investigations which I undertook for Lord Kelvin the source of my papers, but as a fact the subject was brought before me in a somewhat different manner. Some unpublished experiments on the viscosity of pitch induced me to extend Lord Kelvin's beautiful investigation of the strain of an elastic sphere to the tidal distortion of a viscous planet. This naturally led to the consideration of the tides of an ocean lying on such a planet, which forms the subject of certain paragraphs now incorporated in Thomson and Tait's *Natural Philosophy*."

mean motion, it is yet indisputable that Darwin was the first writer to treat the problem in a systematic, thorough-going and original way. Recognizing that at some epoch in the past, the earth was probably a mass of viscous fluid, he set for himself this problem: To determine the bodily tidal distortion of the earth, and the effects of this alteration of figure upon the orbital motion of the moon, and upon the earth's rotation. His papers were communicated to the Royal Society between 1878 and 1882, and are celebrated contributions to the general theory of tides. In these papers he has traced the moon back to close proximity to the earth, when the two, at the breaking off of the moon, were most probably revolving in about 2 h. 41 m. The moon has since receded from the earth under the action of tidal friction, while the rotation of the earth has been slowed up in corresponding degree. It was rendered certain that in the origin of the Lunar-Terrestrial System, the action of tidal friction had played a prominent, if not a paramount part, and the question naturally arose whether it had not been equally potent in the development of other parts of the solar system. When, however, Prof. Darwin came to apply the results to other satellite systems and to the solar system as a whole, it was found that here the effects had been much less considerable than in the case of the earth and moon, owing chiefly to the small masses of the attendant bodies. Thus the major axes of the orbits had perhaps been very slightly increased, and the rotations correspondingly exhausted, but no radical change had taken place. Under these circumstances it was natural that Darwin should drop the subject without further search for extension of the principle he had developed.

About November 1, 1888, while I was still an undergraduate at the Missouri State University I became much interested in the origin of the double stars. The immediate cause of my taking up the subject was the Missouri Astronomical Medal, occasionally awarded by the University to a graduate of highest standing in the Mathematical and Physical Sciences. Having been informed by Prof. W. B. Smith that I was eligible to write for the medal, by virtue of my standing in the Physical Sciences, our conversation drifted on to the probable subject of the Thesis, and in this way he was led to suggest a *criticism* of Darwin's work on the origin of the moon. He remarked: "You may find this only a pocket, already worked out, and not a continuous vein of rich ore, but it seems to me worth thinking of. At any rate I would not advise you to write on the orthodox Laplacean Nebular Hypothesis, for that subject is worn threadbare."

The suggestion of a *critique* of Darwin's work did not quite meet my approval, for I feared the subject was already exhausted and would leave no field for future progress. As I had been observing various double stars for the past two years, and had seen no suggestion regarding their mode of development, it occurred to me that perhaps the tidal theory might find application among the stars. When I had collected such orbits as were

available in the books at my disposal (Humboldt's *Cosmos*, Herschel's *Outlines*, etc.), I discovered to my surprise that unlike the orbits of the planets and satellites, they are very eccentric, though not so eccentric as those of the periodic comets. It was at once evident that it would be hopeless to attempt to explain the origin of the stellar systems, if we could not explain the cause of the high eccentricities of the orbits. The next day I called on Prof. Smith and told him of the discovery that the orbits are very eccentric, and asked whether he thought I might explain this peculiarity on the tidal theory; rubbing his head for a moment in quiet reflection, he replied: "Oh! I see what you mean; you think the dragging of the tides in the bodies of the stars has produced the elongation you find in the orbits. Such an idea can hardly be discussed off-hand, but it is at least worth examining; it may prove fruitful." "That is exactly what I mean," said I, "and you have correctly interpreted my line of thought." After this conversation, which is here reported exactly as it occurred,* there was nothing else before my mind for several days, as I was wholly occupied with finding out whether the problem undertaken was soluble, and, if so, whether it would result in any important Physical Truth. Having established the fact of high eccentricity as thoroughly as the published orbits at my disposal would admit, I set about that same day the problem of explaining the cause of the eccentricities; and as I worked the impression continued to grow on the mind that since the stars are not solid, but self-luminous fluid bodies like our sun, and the two members of a system comparable in mass, the action of each body would produce tides in the other, and the lagging of the tides in the two stars would gradually expand and elongate the orbits as now observed in space. And before I had obtained access to the learned papers which Darwin had communicated to the Royal Society, or even to his article "Tides" in the *Encyclopædia Britannica*, I proved by an elementary process that when the bodies rotate more rapidly than they revolve, the eccentricity of the orbit would gradually increase. Here then was a result confirmatory of the happy intuition, and for the past nine years my energies have been largely devoted to the extension and generalization of the theory of bodily tides in relation to cosmical evolution.

After concluding my undergraduate studies at the University of Missouri, I continued the work at the University of Berlin. It is particularly of that work and the extension which I have since made of it that I shall speak to-night. The theory of tidal friction developed in the *Inaugural Dissertation* presented to the Faculty of the University of Berlin is essentially a special treatment of the general theory as it occurs in nature, while that previously developed by Darwin in connection with the moon and planets is restricted by the condition that the perturbing body is very small. I shall therefore discuss the general case as presented in my own researches.

*As the occasion of my beginning this work has never been published, I trust it will not be thought inappropriate for me to recall it in this paper to the American Philosophical Society.

Suppose we denote an element of the mass of a spheroid by m , and its distance from the axis of rotation by d ; then the moment of inertia is

$$I = \sum m d^2$$

If the spheroid be rotating with an angular velocity y , then Iy will be the moment of momentum of the body about its axis. For a second body whose moment of inertia is I' , and angular velocity z , the moment of momentum is $I'z$.

Following the analogy of Darwin's procedure, we choose a system of units designed to simplify the resulting equations. Let us take as the unit of mass

$$\frac{M M'}{M + M'},$$

and as the unit of length a space Γ such that the moment of inertia of the spheroid about its axis of rotation shall be equal to the moment of inertia of the two spheroids treated as material points, about their common centre of inertia when distant apart Γ . Then we have

$$M \left\{ \frac{M' \Gamma}{M + M'} \right\}^2 + M' \left\{ \frac{M \Gamma}{M + M'} \right\}^2 = I, \text{ or}$$

$$\Gamma = \left\{ \frac{I (M + M')}{M M'} \right\}^{\frac{1}{2}}$$

Let the unit of time be the interval in which one spheroid describes $57^\circ.3$ in its orbital motion about the other when distant Γ . In this case, $\frac{1}{\theta}$ is the orbital angular velocity of the body. The generalization of Kepler's law gives

$$\theta^{-2} I^3 = \mu (M + M'), \text{ and}$$

$$\theta = \left\{ \frac{I^3 (M + M')}{\mu^2 (M M')^3} \right\}^{\frac{1}{2}}$$

Now suppose the two stars to revolve about their common centre of inertia in a circular orbit, with an angular velocity Ω , when the radius vector is ρ . Then the orbital moment of momentum is

$$M \left(\frac{M' \rho}{M + M'} \right)^2 \Omega + M' \left(\frac{M \rho}{M + M'} \right)^2 \Omega = \left(\frac{M M'}{M + M'} \right) \rho^2 \Omega.$$

In a circular orbit the law of Kepler gives $\Omega^2 \rho^3 = \mu (M + M')$; and $\Omega \rho^2 = \mu^{\frac{1}{2}} (M + M')^{\frac{1}{2}} \rho^{\frac{1}{2}}$; and on inserting for $\Omega \rho^2$ its value, we have $\mu^{\frac{1}{2}} M M' (M + M')^{-\frac{1}{2}} \rho^{\frac{1}{2}}$,

which in special units is $\rho^{\frac{1}{2}}$. Now the total moment of momentum of the system is constant, and is given by

$$H = Iy + Iz + \mu^{\frac{1}{2}}MM'(M + M')^{-\frac{1}{2}}\rho^{\frac{1}{2}}\dots\dots\dots(1)$$

The kinetic energy of orbital motion is

$$\frac{1}{2} M \left(\frac{M'\rho}{M + M'} \right)^2 \Omega^2 + \frac{1}{2} M' \left(\frac{M\rho}{M + M'} \right)^2 \Omega^2 = \frac{1}{2} \left(\frac{MM'}{M + M'} \right) \rho^2 \Omega^2 = \frac{1}{2} \mu \frac{MM'}{\rho}.$$

The kinetic energy of rotation is

$$\frac{1}{2} I y^2; \frac{1}{2} I' z^2.$$

The potential energy of the system is

$$- \mu \frac{MM'}{\rho}.$$

By adding all these energies together we get the total energy of the system :

$$\frac{E}{2} = \frac{1}{2} I y^2 + \frac{1}{2} I' z^2 - \frac{\mu}{2} \frac{MM'}{\rho},$$

where E is twice the whole energy.

In the system of special units, $I, \mu MM'$, are equal to unity. If we put $k = \frac{I'}{I}$, we shall get

$$E = y^2 + k z^2 - \frac{1}{\rho}.$$

Let $x = \Omega^{-\frac{1}{2}}$, and then $\Omega^{-\frac{1}{2}} = \rho^{\frac{1}{2}}$, $x = \rho^{\frac{1}{2}}$, and we have finally

$$E = y^2 + z^2 - \frac{1}{x^2}\dots\dots\dots(2)$$

If we suppose the two stars to turn on their axes in the same time in which they revolve in their orbits, so that they show always one face to each other, the motion of the system will be as if the masses were rigidly connected. This condition is given by

$$\Omega = y = z, \text{ or}$$

$$\Omega^{-\frac{1}{2}} = x = y^{-\frac{1}{2}} = z^{-\frac{1}{2}}, \text{ or}$$

$$x^2 y = 1, x^2 z = 1\dots\dots\dots(3)$$

Accordingly we have the system of fundamental equations :

$$\left. \begin{aligned} H &= y + kz + x, \text{ plane of momentum,} \\ E &= y^2 + kz^2 - \frac{1}{x^2}, \text{ surface of energy,} \\ x^3 y &= 1, x^3 z = 1, \text{ curve of rigidity.} \end{aligned} \right\} \dots\dots\dots(4).$$

These equations represent all possible interactions of the system, but in their present form are very difficult to interpret. The general problem to which they give rise seems to be insoluble, but we can solve and interpret them fully for one particular case which is in close accord with the conditions existing in nature; and it is possible to show by analogy that all other cases will be essentially similar to the one of which we shall treat.

By taking the case of two equal stars rotating in the same direction with equal angular velocities, or substituting (3) of (4) in (1) of (4), we reduce the plane of momentum to a particular line of that plane :

$$x^4 - Hx^3 + (1 + k) = x^4 - Hx^3 + 2 = 0, \text{ since } k = 1.$$

The equation of the energy surface passes into the form

$$E = \frac{(H - x)^2}{2} - \frac{1}{x^2}.$$

The curve of rigidity becomes

$$\eta = \frac{H - x}{\sqrt{2}}, \text{ where } \eta = \sqrt{y^2 + z^2}.$$

Every point in the plane of momentum represents one configuration of the system, *i. e.*, one distance apart, one velocity of axial rotation, one moment of momentum of orbital motion. This point therefore determines the dynamic condition of the system, and by the motion of this point we may discover the changes which are taking place in any case that may be imagined. As we have restricted the plane of momentum to one line, the guiding point representing the configuration of the system will simply glide back and forth along this line. In the same manner the surface of energy is now restricted to a curve formed by cutting that surface by a certain plane; the guiding point that would slide along the energy surface is thus restricted to one line of the surface given by the transformed equation. [The reader who may desire to examine this question exhaustively must be referred to my *Inaugural Dissertation, Die Entwicklung des Doppelsternsystems*, Berlin, 1893, R. Friedländer & Sohn.]

As the tides raised in the stars are subjected to frictional resistance, energy is

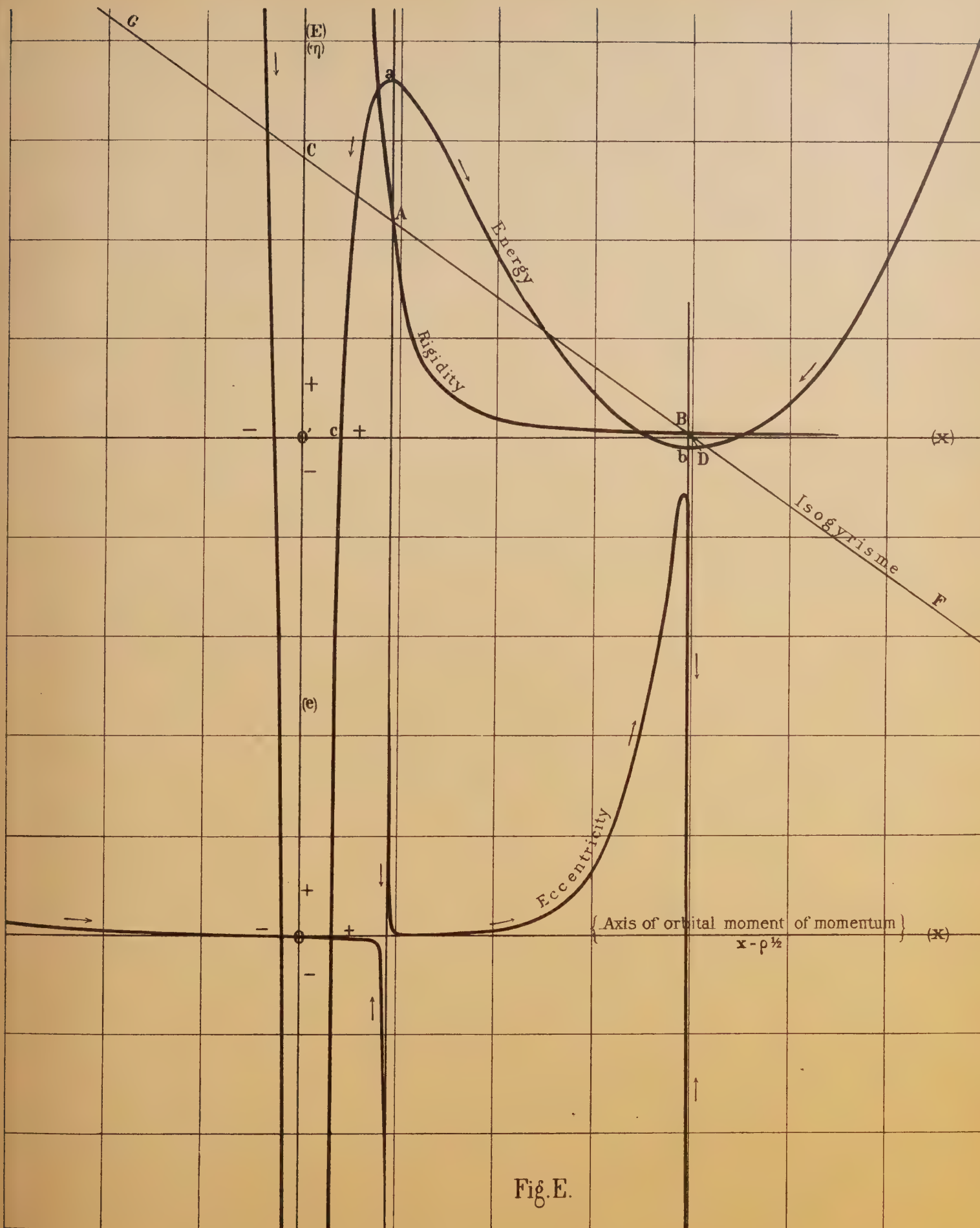


DIAGRAM FOR THE CURVES OF A SYSTEM OF EQUAL STARS, UNDER THE INFLUENCE OF TIDAL FRICTION.

Lower Curve illustrates increase of Eccentricity as the Stars separate.

thereby converted into heat, and lost by radiation into surrounding space; thus the total energy of the system must decrease with the time. Hence it follows that, however the system be started, the guiding point representing the configuration of the system must slide down a slope of the energy curve. In the accompanying illustration the curves are drawn for the value of $H = 4$.

If the guiding point is set at a it may move either of two ways: it may slide down the slope ac , in which case the stars fall together; or it may slide down the long slope ab , in which case the stars recede from each other under the influence of tidal friction. This latter case is the one of chief interest in respect to systems actually existing in space, and the several other ideal cases need not be discussed in this paper. The condition at a is dynamically unstable, and corresponds to that of the system at the instant when the stars are first separated. At this juncture they rotate as a rigid system, but as each is losing energy by radiation, the axial velocities will soon surpass the velocity of orbital motion, and then the tides will begin to lag, and the mutual reaction of the stars will drive them asunder. Thus the guiding point in general slides down the slope ab . This means that as the stars recede from each other, the period of revolution for a long time surpasses that of axial rotation, but that in time the two periods again become synchronous when the guiding point has reached the minimum of energy at b , where the bodies once more revolve as if rigidly connected.

The question now arises with respect to the changes of the eccentricity. The differential equation for the change of the eccentricity is shown to be

$$\frac{1}{e} \frac{de}{dx} = \frac{1}{2x} \left\{ \frac{11x^3(H-x) - 36}{x^3(H-x) - 2} \right\},$$

which, on integration, is put into the form

$$e = \frac{Bx^{18}}{[x^4 - Hx^3 + 2]^{2\frac{3}{8}}} \left\{ \frac{(x \propto a)^{\frac{H}{8a_1}} \exp. \left[\frac{H\beta}{4(a_1^2 + \beta^2)} \arctan \frac{x-a}{\beta} \right]}{(x \propto b)^{\frac{H}{8a_1}} [(x-a)^2 + \beta^2]^{\frac{Ha_1}{8(a_1^2 + \beta^2)}}} \right\}^{\frac{2\frac{5}{8}}{4}} \dots \dots \dots (5)$$

where B is an arbitrary constant; $a, b, \alpha \pm \beta$, are the roots of the biquadratic equation. $x^4 - Hx^3 + 2 = 0$. Equation (5) is illustrated in the lower part of the preceding figure, the origin being shifted downward to O' to prevent confusion of too many curves in one diagram. Now as the guiding point on the energy curve slides down the slope ab , the eccentricity at first very slightly decreases, then increases slowly, finally much more rapidly, until a high maximum is reached, after which it again diminishes, owing to the libratory motion in the system. Thus it is clear that as the stars recede from each other, the orbit becomes highly eccentric, but will ultimately become circular when

the system revolves as a rigid body. This last condition cannot come about while the stars are still contracting and shining by their own light, and hence all visible systems are characterized by highly eccentric orbits.

To leave no doubt that tidal friction is a sufficient cause to account for the elongation of the orbits of the double stars, I applied the theory to a special case, in which the masses, distances and velocities are known. Taking two spheroidal fluid masses each three times as large as the sun, expanded to fill the orbit of Jupiter, and set revolving in an orbit of 0.1 eccentricity at a mean distance of 30 astronomical units, I find that by tidal friction the major axis of the orbit will be increased to 48 astronomical units, while the eccentricity will rise to 0.57. In this problem the masses are set rotating at such a rate as will produce an oblateness of about $\frac{2}{5}$, so that the equilibrium is stable. Different conditions will produce different results, but it is easy to see by this numerical example that tidal friction is a sufficient cause to account for the observed elongation of the orbits of double stars.

Though it may be supposed that there could be little doubt of the generality of the law of the eccentricity which I inferred in 1888, yet the importance of this fundamental fact of the universe is so great that I did not feel satisfied till all the observations of double stars had been examined anew and this conclusion touching the eccentricity established upon the most unshakable foundation. At length I have been enabled to show by the most exhaustive investigation of stellar orbits ever attempted, that the most probable eccentricity is 0.48; while on the other hand extremely eccentric and extremely circular orbits are equally rare, and must be referred to some unusual circumstances. Thus of the 40 orbits now well-known, it turns out that none lie between the eccentricities 0.0 and 0.1; two between 0.1 and 0.2; four between 0.2 and 0.3; eight between 0.3 and 0.4; nine between 0.4 and 0.5; nine between 0.5 and 0.6; two between 0.6 and 0.7; four between 0.7 and 0.8; two between 0.8 and 0.9, and none between 0.9 and 1.0. It follows therefore that by whatever process the stars developed, their orbits assumed a form which is about a mean between the nearly circular orbits of the planets and the extremely elongated orbits of the periodic comets.

Now a double star can originate by but one of two processes: either such a system is the outgrowth of the breaking up of a common nebula, or it is made up of separate stars brought together in a manner analogous to that involved in the capture of a comet. That these systems are not the outgrowth of accidental approach of separate stars we may at once affirm; for if we suppose them to be so produced, there being no third disturbing body which acts like the sun in the capture of comets, the captured star would recede to a distance equal to that from whence it came. In that event we should observe stars moving in paths of very immense extent, and consequently

revolving at the quickest in some hundreds of thousands of years. If the paths be elliptical, the major axes of these ellipses would be of the same order of magnitude as the distance which separates us from α Centauri; while if the paths be parabolic or hyperbolic, the two objects would pass and then separate forever. On the other hand we can conceive of nothing which could diminish the dimensions of a very long ellipse, unless it be something analogous to a resisting medium. Such a medium to be effective in reducing the size of the orbits would have to act for a great period of time, and besides would probably be visible in space as diffused nebulosity. No nebulosity is observed about revolving double stars, nor is there any evidence of a sensible resisting medium either among the stars or in our own solar system. We may therefore reject the idea that the dimensions of the orbits were originally very large, and have since been diminished. As the orbits are now of the size of those of our greater planets, and therefore comparatively small, it follows that the stellar systems have originated by some process other than by the union of separate stars.

As a nebula is a very rare and expanded mass, and is yet held in equilibrium by the pressure and attraction of its parts, it necessarily rotates very slowly; and hence when it divides into two parts under the acceleration of rotation due to secular condensation, the orbit pursued by the detached mass must be of small eccentricity. For even if the forces producing separation could be exerted suddenly to produce a violent rupture, the detached mass in pursuing its eccentric orbit would again come to periastron, where it would encounter resistance in its orbital motion, and the result of the grazing collision would be a diminution of the size of the orbit, and consequently an exaggeration of the resistance at the next periastron passage; in this way the system would very soon degenerate into one mass. On the other hand were the initial eccentricity small, the newly-divided masses would pass freely, and when the orbit eventually became highly eccentric the secular contraction in the size of the masses would prevent disturbance at periastron. Subsequent collision could not possibly occur, because the periastron distance would steadily though perhaps only slowly increase as the stars are pushed asunder and the orbit is rendered constantly more and more eccentric.

It follows therefore that in the beginning the orbits are only slightly eccentric, and that the eccentricity is developed gradually as the result of secular tidal friction working through immense ages. Accordingly in the elongation of the orbits now observed we see the trace of a cause which has been working for millions of years. The existence of this cause and its effects on stellar cosmogony could probably never be inferred except in the manner by which I approached the problem. On the one hand it appears that we have inferred the true cause of the expansion and elongation of the stellar orbits, while on the other the trace left by this cause has enabled us to detect the existence of

unseen tides in every part of the heavens. In a fluid universe tides necessarily result from gravitation, and are as universal as this great law of nature. In my later researches I have therefore been much concerned to show from the discussion of reliable observations that gravitation is really universal* and consequently that the tides we have assumed actually exist in the bodies of the stars. It is thus made certain that the foundation upon which our cosmogonic speculation rests is as enduring as the Newtonian theory itself.

We now come to the second part of the problem: By what process did the stars separate? In college lectures I had heard the annular theory of Laplace expounded for the solar system, and yet I failed to see how this theory could account for the separation of equal or comparable masses, such as we observe among the stars. Realizing that the double stars are in fact made up of two bodies of comparable mass, I reached the conclusion while still at the Missouri University that there must exist some process by which a nebula divides into equal or comparable parts, in a manner analogous to that of fission among the protozoa. About November, 1889, very soon after I entered upon my studies at the University of Berlin, I found that Darwin had recently published an important mathematical paper on the figures of equilibrium of rotating masses of fluid, and had referred therein to the profound work of Poincaré published about a year before. When I beheld the figures of equilibrium which these mathematicians had computed, I recognized at once the cosmical process I had already assumed to exist; it was indeed a great satisfaction to see a demonstration that under gravitational contraction homogeneous incompressible fluid masses may divide into equal or comparable parts. The next question was: Are there nebulae of this form in the actual universe? In searching over the paper of Sir John Herschel in the *Philosophical Transactions* for 1833, I found some drawings of double nebulae almost exactly like the figures mathematically determined by Darwin and Poincaré. It was no longer possible to doubt that the real process of double-star genesis had been discovered. Further investigation and reflection have confirmed this inference, and I believe we may now accept with entire confidence the result reached at Berlin in November, 1889.

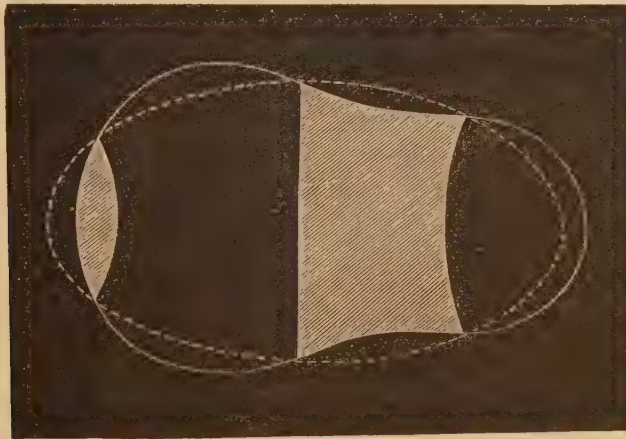
In the first investigation Poincaré begins with the Jacobian ellipsoid of three unequal axes, and imagines it shrinking in such a way as to remain homogeneous, and yet gain constantly in velocity of axial rotation. When the oblateness has become about $\frac{2}{3}$ he finds that the equilibrium in this form becomes unstable, and the mass tends to become a dumb-bell with unequal bulbs—an unsymmetrical pear-shaped figure which I have called the Apoid. As the contraction continues the whole evidently ruptures into two comparable masses, and the smaller will then revolve orbitally about the larger. If

* RESEARCHES ON THE EVOLUTION OF THE STELLAR SYSTEMS, Vol. I: *On the Universality of the Law of Gravitation and on the Orbits and General Characteristics of Binary Stars* (The Nichols Press, Lynn, Mass., 1896).

we suppose either mass to contract still further, it is evident that the rotation will begin to exceed the orbital motion; and the tides raised in either mass by the attraction of the other will lag, and tidal friction will henceforth play just the part we have already described.

Starting from a different point of view, Darwin was already at work on essentially the same problem when Poincaré's paper appeared, and he held his results back for nearly a year longer, hoping to make application of the principle Poincaré had announced. In this second method of treatment two masses of homogeneous fluid were brought so close together that the tidal distortions of their figures caused them to coalesce into one mass; set in motion as a rigid system, the problem was to find the resulting figure of equilibrium. It turned out to be a dumb-bell with equal or unequal bulbs according to the relations of the primitive masses. Thus we see it proved from two

Fig. 1.



The Apoid of Poincaré, showing how a rotating mass of fluid separates into two unequal parts.

independent points of view that a division such as I assumed in 1888 can theoretically take place; and among actual nebulae of space such division seems to be a general law. During the years of 1896 and 1897, I have examined a number of such objects in the southern hemisphere, and find them substantially as drawn by Herschel many years ago. Burnham and Barnard had previously assured me that the interpretation of the figures of double nebulae based on the drawings of Herschel was in accord with the phenomena of nature, but the studies more recently made with the great Lowell telescope supplements their large experience in a very happy manner, and may be said to remove the last doubt that could attach to the division of nebulae by the process of fission.

Before concluding these remarks it ought to be pointed out that in space we have to deal with masses which are not homogeneous, nor are the nebulae by any means incompressible; yet many considerations lead us to believe that in most cases the density of

a nebula is not very heterogeneous, and hence in general the foregoing conclusions would not be greatly modified. In this reasoning I have assumed nothing but that the nebulae are figures of equilibrium under the action of gravitation. That these masses are fluid is certain, for the bright lines of their spectra indicate that they are self-luminous gas; on the other hand the same force which controls the motions of the stars must operate among the particles of the nebulae, and thus determine the figures of the masses in accordance with the laws of mechanics.

As the conditions here assumed certainly exist in the heavens, we need only add that when the masses separate they are probably revolving as a rigid system. When they contract under the influence of gravitation, they must by a well-known mechanical law gain in velocity of axial rotation, and tidal friction then begins expanding and elongating the orbits; in the course of some millions of years we have a double star like α Centauri or 70 Ophiuchi.

The stellar cosmogony here suggested may be regarded as a very general theory. Our solar system is so remarkable that it is uncertain whether a theory which explains the formation of double stars could assign also the cosmogonic processes which have given birth to the planets and satellites. The masses of the planets are very small compared to that of the sun, and the masses of the satellites are equally insignificant compared to those of the planets about which they revolve. Moreover the orbits are very circular, and these various circumstances make our system absolutely unique in the known creation. Yet so far as our researches on the double stars may illuminate the problem of planetary cosmogony, they indicate that the separation took place in the form of lumpy or globular masses—not in rings or broad zones of vapor such as Laplace supposed.

From the survey thus hastily made of a very large subject, it appears that we have taken a step in the generalization of the theory of tides and of tidal friction, and have indicated the probable mode of formation of the stellar systems. Little or nothing is known of the development or even of the mechanism of star clusters; the problem of explaining the more complicated systems must ultimately occupy the attention of astronomers if we are ever to trace the development of the visible universe. As a step in the direction of accounting for the origin of multiple systems, it may be said that observations on triple and quadruple stars have shown that they, too, developed by repetition of the fission process. One or both components of a binary have again subdivided, just as I inferred was the case when still at the Missouri State University in 1888. While the views here expressed are the results at which I have arrived after a partial investigation of the theory of tides and of the figures of equilibrium of rotating masses of fluid and a comparison of these theories with the phenomena observed in the heavens, I reserve the right to modify any opinion or conclusion which future research may show



Drawings of double nebulae according to Sir John Herschel.

to be unsound or incomplete. That tidal oscillations which were first noticed by the navigators of our seas are at length seen to be but special phenomena of a general law operating throughout the universe is alike honorable and gratifying to the human mind. It is equally inspiring to recall that by the known laws of these phenomena we are enabled to trace existing systems through immeasurable time, and thus disclose cosmical history which mortal eye could never witness. In our time it is no longer sufficient to maintain the traditions of the past, to trace the planets, satellites and comets through centuries, and explain observed anomalies in their figures, attractions and orbital motions by the law of gravitation. We must essay to discover the cosmical processes by which the existing order of things has come about. Though it seems probable that a fair beginning on this problem has already been made, a much greater work remains to be done during this and the coming century.

What is needed is a more thorough exploration of the face of the heavens, by astronomers who are familiar with the laws of mechanics ; and a far-reaching investigation of the general theory of tides in viscous liquid and gaseous masses such as the stars and nebulae of remote space. Even if the full extent of the hopes here expressed can be realized only after the lapse of several centuries, I venture to believe that the achievement will not be unworthy of the past history of Physical Astronomy.

ARTICLE V.

ON THE GLOSSOPHAGINÆ

(Plates VI-XV.)

BY HARRISON ALLEN, M.D.

Read before the American Philosophical Society, January 21, 1898.

Having an impression that the genera of bats are best defined by minute characters in the skull, teeth and wing membranes, I am led to review the Glossophaginæ—a sub-family of the Phyllostomidæ, concerning which unsatisfactory accounts exist both as to structure and relationship.

The bats embraced in the group are characterized by a slender protrusile tongue, an elongated jaw and a deeply cleft lower lip.* The temporal impression is faintly marked and the sagitta is absent or confined to the frontal bone. The thumb and forearm are long. The olecranon lies on the upper side of the wing membrane. The canine teeth are long and the upper molars without hypocone. The incisors are so diminutive as to permit the tongue to be freely projected without wide separation of the jaws.

According to P. Osborne (*Proc. Zool. Soc.*, 1865, 82) the thumb aids in the seizure of small fruits, the teeth tear through the skin and the long tongue extracts the semi-fluid contents. As in the Edentata, the elongation of the jaws and tongue has led to the simplification of the teeth. But reduction in number of the teeth has gone on scarcely at all; indeed, the most highly specialized forms are those having the largest number of teeth.

The genera are arranged in three alliances—the glossophagine, the choeronycterine and the phyllonycterine. The first is composed of *Glossophaga*, *Leptonycteris* and probably *Monophyllus*; they certainly relate closely to the Vampyri. The second of the highly specialized and more doubtfully placed group of *Choeronycteris*, *Lonchoglossa* and *Anura*,

* Zoölogists are indebted to Prof. W. Peters (*M. B. Akad.*, Berlin, 1868), for a revision of the group of the glossophagine bats. The diagnoses are unfortunately sometimes inadequate and without critical analyses of synonymy. The confusion arising from the circumstance last named is to be acknowledged; as a result, the task of identification when not aided by inspection of type specimens is difficult. Dobson in his well-known catalogue of the Chiroptera in the British Museum, 1878, follows Peters closely—often indeed merely translating or paraphrasing his language—and on the whole shows less acumen than characterizes his admirable work elsewhere.

is probably also of Vampyrine origin. The third division contains but a single genus, viz., *Phyllonycteris*. It is so near *Brachyphylla* that it would be easy to effect the transition and remove the genus to the alliance expressed by the term brachyphylline. It is akin, therefore, if not annectant, to the subfamily Stenoderminæ.*

The material available for the study just completed was not large, and two genera, namely, *Monophyllus* and *Glossonycteris*, I have not seen. I have concluded from the published descriptions of *Glossonycteris* that doubts can be frankly expressed concerning the validity of this genus. Perhaps not enough stress has been laid upon the effects of age in attempting to separate it from *Anura*.

Reliable characters are found in the lower molars. The extension forward of the ridge (anterior commissure) between the protoconid and the paraconid is more marked than in any other group, and is in consonance with the compression of the crowns. The ridge is not spinose, and is scarcely raised. In *Glossophaga* the ridge is constantly as in the Vampyri, but in the other genera it is an extension forward from the protoconid. No trace of hypocone is seen in the upper molars.

The row of glands lying to the outer side of the nostril is discernible in all genera except *Phyllonycteris*. Minute distinctions are found in the degree of development of these glands. They are best developed in the glossophagine group, and least so in the chœrnycterine. In *Phyllonycteris* the ecto-nareal gland-row is occupied by a flattened fold of skin which becomes incorporated with the nose leaf.†

The proportions of the width of the third and fourth digital interspaces taken at the distal ends of the metacarpal bones when the wing is extended is found to be as valuable an aid in determining affinities as elsewhere in the order. In like manner the shapes of the terminal cartilages of the fourth and fifth digits, the arrangements of muscles and nerve markings of the wing membrane are noted as furnishing excellent characters.

The following scheme of interdigital diameters is given :

	Second Interspace.	Third Interspace.	Fourth Interspace.		Second Interspace.	Third Interspace.	Fourth Interspace.
<i>Glossophaga soricina</i>	2	12	17	<i>Lonchoglossa</i>	2	16	23
<i>Glossophaga truei</i>	2	11	15	<i>Anura</i>	3	15	30
<i>Leptonycteris</i>	3	15	25	<i>Phyllonycteris</i>	3	13	25
<i>Chæronycteris</i>	2	11	20				

Enough can be gleaned in the way of inductions from the shapes of the anterior

* In a paper by myself, entitled "On *Ametrida minor*" (*Proc. Bost. N. Hist. Soc.*, 1892), I used inadvertently the term *Stenodermatidæ* for this subfamily.

† The genera of the remote megaderminine genera are in like manner distinguished by characters in rows of glands as contrasted to folds of skin, though the structures are here not ectonareal, but infranareal. In *Megaderma* the glands are distinct, while in *Lyroderma* and *Lavia* they are supplanted by a skin-fold which becomes an integral part of the nose leaf.

extremities and the details in the phalanges and terminal cartilages to warrant the introduction at this place of a few remarks on the subject of flight.

Leptonycteris. The greatest restriction in the movements of the digits is found in *Leptonycteris*. The sharp flexure of the second row of the phalanges on the first impede rapidity of flight, while the axially disposed, terete terminal cartilages show absence of strain. The second and third metacarpals always maintain an acute angle to the forearm.

Glossophaga and *Chaeronycteris*. These genera resemble *Leptonycteris*, differing therefrom in degree only in the greater degree of interphalangeal flexure and in the angulation of the second and third digits to the forearm.

Anura shows scarcely any tendency to flexure or angulation of the parts above named while the terminal cartilages of the third and fourth digits are markedly deviated from the axial positions and thus appear to correlate with increase of wing strain.

Lonchoglossa is intermediate between *Anura* and the preceding group.

Phyllonycteris shows an isolated position from the foregoing group as a whole, on account of the terminal cartilage of the fifth digit being entirely embraced by the wing membrane. It is a curious circumstance that the remote *Leptonycteris* exhibits a similar peculiarity.

It cannot escape notice in studying the group that the extraction of soft pulp from a fruit is not unlike the lapping of blood. Acquirements apparently so diverse as fruit-eating and blood-taking are not so improbable as they might appear to be at first sight. Geoffroy, who established *Glossophaga*, yet who had no knowledge of the habits of the species, concluded from the structure of the tongue that the animal was a blood-sucker.* In adapting the head so as to create a blood-lapping from a pulp-extracting form the greatly elongated jaws are shortened, the face flattened, and the teeth become knife-like. In this manner we may trace the transitions which have taken place in the Vampyri in creating on one hand the *Glossophaginæ* and on the other hand the *Desmodinæ*.

In *Glossophaga* the *Flexor carpi radialis* passes along the upper border of the radius as far as the distal third, at which point it crosses the curved radius to reach the carpus. In *Chaeronycteris* and *Lonchoglossa* the tendon of this muscle lies to the lower border of the nearly straight radius.

The *Flexor sublimis digitorum* has the weakest development in *Chaeronycteris*, in which form it supplies the first and fourth digits only. In *Phyllonycteris* it omits only the second, while in *Lonchoglossa* and *Glossophaga* it supplies all the digits.

* The stomach in the *Glossophaga villosa* Rengger (*Naturgesch. der Säugethiere von Paraguay*, Basel, 1830, 80) was found to contain blood with remains of insects. It is not known what forms would now be included under this title. See remarks on *Anura*.

The origin of the *Glossophaginæ* is easily traceable to the group denominated by Peters the Vampyri. But the division between the genera composing the Vampyri is of a character to suggest two groupings at least, and the term Vampyri is best used in a restricted sense. Indeed, it is a small cluster of four genera only (*Vampyrus*, *Macrotus*, *Schizostoma* and the aberrant *Hemiderma*), which possess a large, triangular, first upper premolar and an inflated, weak periotic region.

Of the second group (Phyllostomi), of which *Phyllostoma* is the type, I have imperfect knowledge—having studied besides this form the genera *Lonchorhina* and *Lophostoma*. But they agree in having the first upper premolar small and acicular, a peculiarity I find figured in Gervais (*Exp. du Sud.*) as characteristic of *Tylostoma* and *Monophyllum* (*Dolichophyllum*). I infer that *Trachyops*, *Phylloderma* and *Mimon* are members of this group from Dobson's statement (*Br. Cat. Chir.*) that they resemble *Phyllostoma*. I have no satisfactory knowledge of the periotic region in this group, but can say that it is boldly defined, concave, and not inflated in *Phyllostoma*, *Lonchorhina* and *Lophostoma*.

Now it has been seen that the *Glossophaginæ* yield two groups—that of the Glossophagi and that of the Lonchoglossi. In my judgment these do not have a common origin. The Glossophagi agree with the Vampyri as above restricted in the shape of the first upper premolar and the inflated periotic region, while the Lonchoglossi are much nearer the Phyllostomi. *Chaenycteris* possesses a triangular premolar (with large denticles) and a moderately truncate concave periotic region, but its other characters, taken as a whole, connect the form intimately with the Glossophagi.

The taxonomic value of the terminal cartilage can be determined only by the examination of extended series. At first I had inferred that the shapes of the cartilages of the fourth and fifth digits were of considerable value. But inspection of the largest number of individuals of the most common species—namely, *Glossophaga soricina*—gave me an impression that they were really variable structures; thus in one individual from Costa Rica they were both spatulate; in another from Bahama Islands they were both aciculate; and yet in a third specimen from the last-named locality the fourth digit was spatulate and the fifth aciculate. Nevertheless the variability itself is of interest and I have, therefore, figured the cartilages, believing that after extended observation they may assist in more firmly defining the minor groups of species than is now the case.

GLOSSOPHAGA.

Upper incisors in a continuous row. Length of forearm not exceeding 36 mm.; thumb, 8 mm.; calcar present; the tail is short with free tip on the dorsum of the interfemoral membrane. Proencephalon creates an eminence on brain case; fronto-maxillary inflation conspicuous; mastoid process small.

Dental formula: i. $\frac{1}{4}$ — c. $\frac{1}{1}$ — prm. $\frac{2}{3}$ — m. $\frac{3}{3}$ = 21.

The *Flexor profundus digitorum* supplies second and third digits only. The *Semimembranosus* and *Biceps femoris* are absent. The tendons of the *Gracilis* and *Semitendinosus* closely approximate and give the appearance of being fused, but by gentle traction they can be shown to be distinct.

Pallas first described *Glossophaga soricina* as having no tail (*Misc. Zoölog.*, 1766, 48), the type being a female. He subsequently described and measured a second specimen (*Spicil. Zoöl.*, III, 1767, 24), a male, which he dissected. He now noted the presence of a short tail and figured the skeleton in which the tail is plainly seen. Geoffroy accepted the first description as final, and proposed a separate name (*G. amplexicaudata*) for the assumed new species possessing a tail. Gray (*Ann. and Mag.*, N. S., 1838, II, 490) acting on these erroneous premises proposed the name *Phyllophora* for *Glossophaga amplexicaudata*. Gervais (*Expn. Amerique du Sud.*, 1855, II, mem., 40) sustains Gray's position without comment. Peters set the matter to rights in 1868, over a hundred years after Pallas' first simple error of observation.

Of the elaborate measurements of Pallas those taken of the male are the most accurate and include those of the skeleton as well. The figure of the head by Geoffroy also conforms in vertical measurement. The width of the basal part of the nose leaf is less than in our figure. Pallas, Geoffroy and Spix all accurately figure the interfemoral membrane as approaching the ankle, certainly reaching a point below the level of the middle of the tibia, which is the distance given by Dobson.

The fact that the two forms of *Glossophaga* differ so widely makes it desirable that the characters of the first recorded species be carefully noted. A review of the original description of Pallas is of restricted value, other than the anatomy of the soft parts, notwithstanding the praise Geoffroy and Dobson award it. Geoffroy states he had dissected an alcoholic specimen and confirmed Pallas' observations. But Pallas did not note so conspicuous a fact that in the first digit the metacarpal bone is much shorter than the combined lengths of the phalanges. The cranial and dental outlines are worthless;* but one cannot gainsay the value of the figure of the fimbriated and elongated tongue.

Synoptical Table of Genera.

I.	Glossophagina vera.	{	Palatal portion of premaxilla forming a rostrum in advance of median incisive foramen;
			gland mass confined to sides of nose leaf; occipito-squamosal suture without foramen;
			tympanic bulla separated from postglenoid process by a conspicuous interval; ethmoid
			bone convex in brain case; no ectopterygoid lamina; in third to fifth digits first
			phalanx smaller than second; fimbriae not confined to tip, but extending well back
			along the tongue.

* Gervais (*l. c.*) believes the form is not *Glossophaga* at all, but *Hemiderma*.

- a.* Median upper incisors larger than lateral; premolars $\frac{2}{3}$; crown of lower canine with base lying inside position of lateral incisor; median incisor foramen barely in advance of paired foramina; upper incisors inclined; pit over proximal third of face vertex.
- b.* Upper incisors in continuous row; molars $\frac{3}{4}$; thumb one-fourth the length of forearm (31-34 mm.).....*Glossophaga*.
- b.* Upper incisors with wide interval between centrals; molars $\frac{2}{3}$; thumb one-sixth the length of forearm (45 mm.).....*Leptoncycteris*.
- a'.* Median upper incisors smaller than lateral; premolars $\frac{2}{3}$; crown of lower canine with base not lying inside position of lateral incisor; median incisor foramen well in advance of paired foramina; upper incisors vertical.
- c.* Lower canine compressed, with cingulum; metacarpal bone of thumb exceeds length of phalanges.
- d.* No phalanx to second digit of manus; premolars $\frac{2}{3}$; tail present; thumb one-seventh the length of forearm (42 mm.).....*Chernocycteris*.
- c'.* Lower canine rotund, no cingulum; metacarpal of thumb equal length of phalanges.
- d'.* Phalanx to second digit of manus; tail present; thumb one-eighth the length of forearm (38 mm.).....*Lonchoglossa*.
- d''.* No phalanx to second digit of manus; no tail; thumb one-sixth the length of forearm.....*Anura*.

II.

Glossophagina aberrantia.

Palatal portion of premaxilla not rostrum-like; gland mass crosses muzzle back of nose leaf; tympanic bulla almost touches postglenoid process; occipito-squamosal suture with large foramen; ethmoid bone not convex in brain case; an ectopterygoid lamina. In third to fifth manal digits first and second phalanges equal; premolars $\frac{2}{3}$; molars $\frac{3}{4}$; fibræ of tongue at tip only.

Tail present; exceeding short interfemoral membrane; thumb one-fourth the length of forearm (45 mm.).. *Phyllonycteris*.

Glossophaga soricina Pallas.

Auricle emarginate at upper half of the outer border; internal basal lobe free from head and indications of basal ridge. Lappet in side of the external basal lobe stout, pointed. Wing membrane from ankle. Terminal cartilage, fourth digit spatulate. Rudiment of an ascending process from the zygoma.

Auricle subrounded, internal basal lobe with suggestion of vertical ridge, outer margin of auricle sinuate; external basal lobe large, obtuse, retroverted, internal lappet a mere projecting nodule. Tragus straight on inner, convex or obscurely serrate on outer, margin. The nose leaf hairy and small, midrib confined to the pedicle. The leaf proper projecting nearly one-half its length above the conspicuous gland mass. The upper lip as well as the borders of the groove in the upper lip furnished with four to nine minute warts. Above, the fur is dark, sooty gray, at the tip the remainder of the hair being lighter but nowhere white. Beneath paler, unicolored. Interfemoral membrane almost

as long as tibia. The calcar is one-half the length of the tibia. The interfemoral membrane is often incised rather than semicircular.* The tip of the tail projects from the free margin of the interfemoral membrane. Tongue on dorsum free from retrose papillæ.

The first phalanx of the first digit is as long as the metacarpal. Entire digit one-fourth or nearly one-fourth the length of the forearm (10 to 40, or 8 to 36). The first phalanx of the second digit is one-thirtieth the length of the metacarpal; the entire digit is not as long as the third metacarpal. The first phalanx of the third digit is smaller than the second; the third is flexible; the separation from cartilage tip is indeterminate. Metatarsi equal. The row of first phalanges of toes equal.

The Skull.—The brain case papyraceous; the position of the body and hemispheres of the cerebellum—the mesencephalon and prosencephalon—being clearly outlined on the periphery. Pretemporal crests scarcely defined and not continuous with the orbital margin; mesotemporal not seen; posttemporal not distinct from the occipital.

The face vertex is flat with shallow median depression over the ethmoid bone. The convex nasal bones are outlined by grooves, of which the median is the widest and deepest. Each nasal bone is incised on its free margin at the anterior nasal aperture. The sides of the face are convex, with a conspicuous, though small fronto-maxillary inflation. The infraorbital foramen answers in position to the junction of the premolars. The lateral border of the anterior nasal aperture is produced; between it and the prominence over the canine tooth a groove is defined. The height of the alveolus is one-third the width of the neck of the canine, and one-seventh the vertical diameter of the anterior nasal aperture. The posterior border of the hard palate near the zygomatic root is spinose. The palatal notch at the mesopterygoid fossa is acutely incised, carried back to a line answering to the glenoid notch and is without median spine. It reaches a point opposite the posterior third of the zygomatic arch. The tip of the pterygoid process lies opposite the oval foramen. The ascending process of the zygoma is inconspicuous and rounded. Base of cranium with prominent, median, vomerine ridge. The lateral depressions on the basioccipital are conspicuous, the mastoid process is obtuse. The tympanic bone is separated from the postglenoid process by an interval. The coronoid process of the lower jaw is carried above the level of the condyle and is subacuminate. The angle is hamular and deflected outward with a notch between it and the lower border of the masseteric impression and projects backwards slightly beyond the condyloid process. Symphysis not carinate. The junction of the ethmoid and sphenoid bones in brain case convex.

The Teeth.—The teeth of *Glossophaga* are the best defined of any of the group. The cusps are sharp, the incisors and premolars are adapted for cutting, and the molars

* Geoffroy expressed it thus, "coupée en angle rentrant," but this shape is often absent.

for grinding. In the upper jaw, with the exception of an interval on either side of the canine, all the teeth are contiguous.* In the lower jaw there is no interval on either side of the canine, for the lateral incisor and the first premolar are in contact with it. The upper incisors are arranged in a small arc, which is smaller than the space between the canines.

The central incisor is hatchet-shaped, the outer margin concave. The lateral incisor is smaller than central, with inner border twice the length of the outer. The canine is concave on the palatal surface. The premolars are triangular subequal, yet the heel of the second tooth is twice the size of the first. The cingules are scarcely discernible. The first molar is subtriangular with W-shaped crown reduced, the fluting on the paraconid, rudimental; the metacone is united to protocone by a ridge. The second molar is subquadrate, W-pattern scarcely reduced; the fluting on the paracone marked; the ridge from the metacone not reaching the protocone, but a distinct though narrow valley intervening. The third molar is one-half the size of the second, the second V being rudimental. The longitudinal axis of both second and third molar is oblique to axis of the alveolar processes. The third molar slightly overlaps the second at the buccal border.

The lower incisors are provided with flat smooth edges to the crowns and are adapted to crushing rather than to cutting food. The canine is directed slightly backward and is provided with a small heel. The premolars are triangular, equal, the bases increasing in thickness from before backward. The molars exhibit marked commissural extension in advance of protoconid and paraconid. The hypoconid is cuspidate and as high as metaconid; all the teeth are much alike, but become progressively smaller and narrower from the first to the third, while the extension in front of the paraconid and protoconid become less and less marked. The third tooth is not more than two-thirds the length of the first.

In a skull of an embryo which measured 8mm. long, the lower jaw projected well in front of the upper and bore the deciduous canines. The shapes of the incisors and premolars could be discerned, while the upper jaw was edentulous.

In an adult which retained the right upper lateral incisor only and the molars were much worn, the only teeth in the upper jaw that were in contact were the second and third molars. In the lower jaw the third molar was separated from the tooth both the first and third. The lower incisors were much worn and placed slightly in advance of the lateral teeth. I am inclined to believe these are variations due to advanced age.

* The upper incisors as represented by Leche (*Studier öfver Mjolkdentitionen och Tandernas Homologier hos Chiroptera*, 1876, Tab. II, VII) do not touch.

Glossophaga truei, n. s.

In the *Proc. U. S. Nat. Mus.*, XVIII, No. 1100, 1896, 779, I described a new species of *Glossophaga* under the name *G. villosa*. Since Rengger (*l. c.*, p. 80) described in 1830 a species under this name I have concluded to rename the form, notwithstanding that the species is quite different from the genus *Glossophaga* as now restricted. See remarks under *Anura*. I take pleasure in dedicating this species to the accomplished Curator of Mammals of the National Museum, Mr. F. W. True. I herewith reproduce the description, which now has the advantage of appearing with appropriate figures of the head, skull and teeth.

It is a remarkable circumstance that the genus *Glossophaga*, while the most common of any of the forms embraced in the group of Glossophagi, and has been collected from the widest range of any of its race, should have presented degrees of variations so low as never to have permitted the recognition of more than a single species. The complicated synonymy successfully unraveled by Peters, it is true, contains a number of names of species, but these were proposed through misapprehension of assumed generic values and bear no relation to questions of specific distinction.

A careful study of two specimens (Nos. 9522 and 9523) belonging to the United States National Museum has convinced me of the necessity of recognizing two species of *Glossophaga*—namely, *Glossophaga soricina* and the one which I here name

Glossophaga truei.

Auricle entire on outer border or slightly emarginate. Internal basal lobe bound down to head without trace of ridge. Excepting in length of head and trunk everywhere smaller than *G. soricina*. The ascending process of the zygoma twice the size of the same part in that species. Wing membrane from distal fourth of tibia. The terminal cartilage of the fourth digit terete.

The auricle is without ridge at base of the internal basal lobe, which is scarcely defined and closely bound down to head; outer margin almost entire; external basal lobe and nodule inconspicuous. Tragus with trace of serration on outer margin, basal lobe large, quadrate.

The nose leaf, hairy, without midrib at internarial pedicle, projecting scarcely at all above the simple gland mass of the upper lip, which it almost entirely occupies. Thumb one-fourth the length of the forearm—namely, nine to thirty-two. The tail had evidently occupied a position similar to that seen in *G. soricina*. It had been removed in preparing the skin.

Based on skins of two adults : No. 9523, U. S. N. M., La Guayra, Venezuela ;* and No. 9522, U. S. N. M., co-types.

No. 9523, U. S. N. M., fur soft, shrew-like ; dull ash at basal two-thirds, sooty at apical third ; it extends along the entire length of the dorsifacial region. No. 9522, U. S. N. M., quite the same, but is dark brown instead of sooty.

The skull † closely resembles that of *G. soricina*, but is smaller and thinner walled. The ascending process of the zygoma is longer and more pointed than in the species just named ; the palatal notch is less acute. The fronto-maxillary inflation is conspicuous. The symphysis menti is carinate. The angle of the lower jaw projects backward slightly beyond the line of the condyloid process. The brain case is 12 mm. and the face 7 mm. long.

The upper central incisors broad with slightly concave cutting edges ; the lateral incisors are narrow with oblique cutting edges. The premolars are slightly separated from one another and the second premolar from the first molar ; they are compressed, subequal, and triangular ; the second premolar is thickened posteriorly. The other teeth closely resemble those of *G. soricina*. The first upper molar is longer than the second and the second longer than the third ; there are no ridges extending from the paracone to the metacone. The third upper molar does not overlap the second molar at the buccal border.

The muscle fascicles and nerve markings of the endopatagium disposed as in *G. soricina*. This system is the weakest of any of the group of the Glossophagi. The terminal cartilages are throughout terete.

On the whole the descriptions of Pallas and of Geoffroy agree well with *Glossophaga soricina* of Peters' revision, and exclude those specimens here embraced under *G. truei*. In Geoffroy's figure ‡ the measurements of the nose leaf agree with those of *G. soricina*, but the shape of the tragus and internal basal lobe of the auricle are like those of the form under consideration. But the figure is evidently based upon a dried specimen.

The isolation of the premolars in *G. truei* answer fairly well to the arrangement of the teeth in an old example of *G. soricina*. This is an interesting fact, inasmuch as it suggests that senile characters in one species may be the same as those found in young adult life of another.

The following proportions are noteworthy : The first phalanx of the third digit is longer than the second. The third metacarpal bone is as long as the forearm. The

* It is not certain that the locality here given is the correct one. The record in the National Museum catalogue is imperfect.

† In addition to the skull in the type specimens, I possess a skull from Brazil presented by the late Mr. Harte, which answers to the above description.

‡ *Ann. du Mus.*, 1810, XV, Pl. XI.

forearm is 1.15 mm., the smallest in the group. The calcar is one-third the length of the tibia. The first phalanx of the first toe extends slightly beyond the first phalangeal joint of the second toe. The first row of phalanges decreases progressively from the second to the fifth toe.

Type.—No. 9522, U. S. N. M.*

Measurements of Glossophaga truei.

	Millimeters.
Head and body (from crown of head to base of tail)	45
Head and forearm.....	32
First digit :	
Length of first metacarpal bone.....	4
Length of first phalanx.....	4
Second digit :	
Length of second metacarpal bone.....	25
Length of first phalanx	2
Third digit :	
Length of third metacarpal bone.....	30
Length of first phalanx.....	11
Length of second phalanx.....	14
Length of third phalanx	6
Fourth digit :	
Length of fourth metacarpal bone.....	27
Length of first phalanx	9
Length of second phalanx	9
Fifth digit :	
Length of fifth metacarpal bone.....	27
Length of first phalanx	8
Length of second phalanx.....	8
Length of head.....	21
Height of ear.....	11
Height of tragus	3
Length of tibia.....	11
Length of foot	8
Length of interfemoral membrane.....	9

MONOPHYLLUS.

Upper incisors not in a continuous row. The first and second upper molars with hypcone. Length of forearm, 37 mm.; length of thumb, 10 mm. The tail projects from the margin of the short interfemoral membrane. The proencephalon does not create an eminence on the brain case. No vertical line is found on any of the interdigital spaces.

Dental formula : i. $\frac{4}{4}$ — c. $\frac{1}{1}$ — prm. $\frac{2}{3}$ — m. $\frac{3}{3}$ = 21.

* The measurements of No. 9523, U. S. N. M., are the same as in No. 9522, U. S. N. M., excepting in the second phalanx of the third manal digit, which is but 12mm. long.

The single specimen of *Monophyllus* which was available was that of a skin of an adult (No. 83347, ♀, U. S. N. M.) obtained by exchange from the Berlin Museum. The genus is in close alliance with *Glossophaga*—closer, indeed, than any two genera of the group. The retention of the hypocone in the first and second upper molars, the presence of a keel on the symphysis of the lower jaw and absence of the vertical line in the interdigital spaces, separate the two forms. Other characters if they existed unassisted by those just named would be those of relation and proportion. The presence or absence of the calcar could not be determined.

Monophyllus redmani Leach.

Auricle with blunt tip, scarcely emarginate on outer border. Wing membrane from basal third of the tibia: terminal cartilage of the fourth digit, spatulate. Marked rudiment of ascending process from the zygoma. Nose leaf, upper lip and membrane much as in Glossophaga truei.

The auricle resembles *G. truei* nearer than *G. soricina*. It is blunt at tip, scarcely at all concave on the outer margin. A faint emargination is noted on the inner margin which may be exaggerated in the dried skin. The external basal lobe was everted by the method used in preparing the specimen. The parts do not differ from those studied in *Glossophaga*. The tragus is blunt, presenting two coarse sinuations at the outer side and two denticulations at the base. The nose leaf, upper lip and mentum almost precisely the same as in *G. truei*. No warts are anywhere present.

Fur above is dark brown; the head, neck and shoulders a lighter shade than the back of thorax and loin. Examined with a lens, the fur has an admixture of fine gray hairs, which are more numerous on head, neck and shoulders than elsewhere. The fur beneath is gray and brown, about equally admixed. Both above and below the hair is unicolored. Sparse gray hairs extend below on arm to elbow and slightly over the endopatagium. The legs are naked.

There is no vertical line on the membrane of any of the interdigital spaces. The endopatagium exhibits a few coarse vertical lines. The fourth interdigital space is obscurely areolate.

The skull was mutilated at occiput and posterior third of the base. It closely resembles *Glossophaga*. The fronto-temporal crest is more defined, while the fronto-maxillary inflation is less defined than in that genus. The posterior palatine notch, narrow. Seen from above, the posterior border of the infraorbital foramen appears as a blunt spine. A narrow but well-defined groove extends the entire length of the face, beginning at a foramen near the pretemporal ridge. The ascending process from the zygoma is greatly in excess of the same character in *Glossophaga*. The external auditory opening

is smaller than in the genus just named. The thick skull does not admit of the divisions of the brain being discerned. The lower jaw is more robust—the depression in advance of the angle most marked of any genus in the group; the angle is raised high above the level of the lower border of the high ramus as in the *Lobostomina*; the symphysis is provided with a large keel.

On the whole the skull is more robust in texture and is of a larger animal than *Glossophaga*, but the face structures more extended, and presumably from the symphysal modifications, a longer and more prehensile tongue.

The Upper Teeth.—The incisors are not arranged in a continuous row or in pairs, but intervals* are found between the teeth.

The space between the central incisors is wider than that between these teeth and the laterals. The central incisors are obscurely hatchet-shaped, while the laterals are conical. Wide intervals also exist between the canine and the first premolar and between the first and second premolars. The other upper teeth are contiguous. The premolars are aciculate, compressed, with prominent base conules. The first and second molars are quadrate with conspicuous hypocone. The third molar is more triangular and resembles the first and second molars of *Glossophaga*.

The Lower Teeth.—The incisors are reduced to tubercles, arranged in pairs, which are widely separated both from the symphysis and the canine tooth, though nearer the latter than the former. The central incisor is larger than the lateral. All the other teeth are contiguous, except the second and third premolars, which are separated by an interval equaling that in the upper series. The first premolar is distinctive. It closely resembles the homologous tooth in *Glossophaga* and anteriorly overlies the base of the canine. The second and third premolars are similar to those in the upper jaw. The molars are of the same type as in *Glossophaga*, but elongated and compressed in advance of the protocone and paracone as in *Leptonycteris*.

The comparison of the skull and lower jaw seen from in front with *Glossophaga* is instructive in the differences in the shapes and relations of the shapes of the teeth already noted. The upper canines are observed to be longer and more trenchant in *Monophyllus* than in *Glossophaga*.

Rugæ ten in number, the anterior five undivided and the posterior five divided.

Measurements of Monophyllus redmani.

	Millimeters.
Head and body (from crown of head to base of tail).....	24 "
Length of arm.....	0
Length of forearm.....	37

*According to Dobson's text, the upper incisors are in a continuous row, but they are figured with an interval between the central incisors. In the table of genera all the upper incisors are said to be arranged in pairs.

	Millimeters.
First digit :	
Length of first metacarpal bone.....	4
Length of first phalanx.....	6
Second digit:	
Length of second metacarpal bone.....	34
Length of first phalanx.....	2
Third digit:	
Length of third metacarpal bone.....	38
Length of first phalanx.....	13
Length of second phalanx.....	19
Length of third phalanx.....	9
Fourth digit:	
Length of fourth metacarpal bone.....	35
Length of first phalanx.....	8
Length of second phalanx.....	12
Fifth digit:	
Length of fifth metacarpal bone.....	30
Length of first phalanx.....	9
Length of second phalanx.....	10
Length of head.....	25
Height of ear.....	10
Height of tragus.....	3
Length of thigh.....	11
Length of tibia.....	15
Length of foot.....	11
Length of interfemoral membrane.....	4
Length of tail.....	5

LEPTONYCTERIS.

Upper central incisors separated by wide interval. Proencephalon not forming an eminence on the brain case. No spine at upper margin of the anterior nasal aperture caused by union of the free margins of the nasal bones. Tail none. Second phalanges of third, fourth and fifth digits sharply flexed on the first.

Dental formula: $i. \frac{4}{4} - c. \frac{1}{1} - prm. \frac{2}{2} - m. \frac{2}{2} = 18$.

Leptonycteris nivalis Saussure.

Auricle small, nearly one-half the length of the face, slightly emarginate at basal half outer border. Internal basal lobe scarcely free; external basal lobe convex, inner lappet crescentic. Tragus straight on inner, convex on outer side; basal lobe conspicuous. Nose leaf projects far beyond non-ribbed pedicle. The latter forms a wart-like contour inferiorly. The upper lip is narrow and provided with two inconspicuous nodules. Cartilages at the end of digits are as in Glossophaga. Calcar rudimental, scarcely one-fifth the length of the tibia.

Tongue furnished on sides and dorsum with minute, hair-like papillæ. The side of

the mental groove furnished with an obscure row of minute warts and the chin beyond the groove thickened with gland clumps.

Fur short, villose, longer on neck, above deep ash verging to gray, base white, below paler. On neck, basal part tawny, but abdomen almost unicolored. The hair is slightly whiter at pubis. Distal half of humerus (above and below) hairy—the rest of the limbs, except the base of thumb, second digit and all of dorsum of foot, covered with a sparse growth of short hair.

The muscle fascicles on wing membrane are much the same as in *Phyllonycteris*. They are wide apart generally, but do not extend over so large a field. The reticulated arrangement of fibres near the forearm is conspicuous. The longitudinal lines in the third and fourth interspaces distinct. The nerve markings are characteristic. Both arise from the digits far above the joint, the anterior being at distal third of the fourth metacarpal bones.

The terminal cartilage of the fourth digit scarcely spatulate; that of the fifth digit is terete and not free. In this respect *Leptonycteris* resembles the remote *Phyllonycteris*. The skin in the second interspace is not pigmented.

The Skull.—Skull not papyraceous; proscencephalon not defined. The pretemporal crests subtrenchant and form a short, faint conjoined line with its fellow at the sagitta; the scarcely discernible mesotemporal depressed, not reaching sagitta; posttemporal reaching occipital crest. Face vertex with depression over ethmoid, but the nasal bones are scarcely defined in median line and not separated at all laterally from the concave sides of the face. Fronto-maxillary inflation barely discernible and crossed by the orbital ridge. Alveolar process in height equals one-seventh the width of the neck of the upper canine and one-twenty-second the vertical diameter of the anterior nasal aperture. The depression between the lateral margin of the anterior nasal aperture and the root of the canine tooth much deeper than in *Glossophaga soricina*. Ascending process of zygoma rudimentary. The premaxilla weak in advance of the large incisive foramina; posterior border near the zygoma root not spinose. The rounded notch at the mesopterygoid fossa midway between zygoma root and glenoid cavity. Scarcely any difference observed between the level of the basioccipital and the basisphenoid. The mastoid process acuminate. The tip of the pterygoid process in advance of the oval foramen. The nasals are incised at the anterior nasal aperture. The angle of the lower jaw acute, not hamular; it is on the same plane with the masseteric impression, not separated therefrom inferiorly by a notch, and projects backward beyond the condyloid process. Symphysis not carinate. The lower border of the masseteric impression carried in a semi-circular line beyond the horizontal ramus.

The Teeth.—Teeth crowded for the most part. Upper incisors as in *Glossophaga soricina*; the central hatchet-shaped, separated by an interval. The lateral incisors as

large or larger than centrals. Canine concave on palatal surface. The first premolar without basal cusp and separated from the canine and the second premolar. The second premolar with basal cusp and in contact with the first premolar. The first molar much larger than the second, the paracone subtriangular, the outer surface of the paracone and mesacone are scarcely at all fluted, hence the W-pattern not evident. The second molar without fluting on the rudimental mesocone, hence the posterior limb of the second V is absent.

The single lower incisor which is seen in the two examples lies in close contact with the canine. The canines are large and divergent, projecting to the inner side of the lateral incisor. The three premolars are triangular with conspicuous cingules; lingual aspect of the first premolar concave and in contact with the canine; the second free from the first and the third premolar. The protoconid with a long anterior extension which has the value of a second functionalized cusp. The paraconid is small and placed slightly back of the protoconid. The mesoconid is higher than either of the other elements, and together with the hypoconid form a low, broad heel. Molars slightly overlapping at buccal borders; the metaconid and hypoconid are of great size with wide valley.

Metatarsi equal; first row of phalanges decrease progressively from the second to the fifth.

The measurements of Dobson do not agree in some respects with the three specimens examined. The thumb is smaller, while the first phalanx of the third finger is much larger. He states the "tail none or exceedingly short."

In the chœrnycterine alliance the genera *Chœrnycteris*, *Lonchoglossa* and *Anura* are placed. They have in common three premolars and three molars in each jaw.*

CHÆRNYCTERIS.

Naked skin fold defining nostril laterally. Pterygoid process in contact with tympanic bone. No phalanx to second digit. Length of forearm, 42 mm.; thumb, 7 mm.

Dental formula: i. $\frac{4}{4}$ — c. $\frac{1}{1}$ — prm. $\frac{3}{3}$ — m. $\frac{3}{3}$ = 22.

Chœrnycteris mexicana Tschudi.

Auricle subelliptical, emarginate on posterior border; internal basal lobe large, entirely free from the head and hairy; external basal lobe small, acute; internal lappet conspicuous. Tragus elliptical; basal lobe simple, deflected backward.†

Interfemoral membrane longer than tibia, semicircular. Calcar half the length of the

* The only other forms possessing the same armament are the remote genera *Vespertilio*, *Cerivoula*, *Natalus* and *Thyroptera*.

† In one specimen the tragus exhibited near the tip two papillæ seen on both the anterior and posterior borders and an additional cluster of three on the posterior surface.

tibia; the tip projects slightly beyond the interfemoral membrane; wing membrane attached at a point midway on metatarsus. Nose leaf acuminate, sparsely hairy. Internareal pedicle with midrib; below two warts at median line in the short lip; outer flange at the nostril broad, tumid and gland-bearing. The gland mass proper well defined, but not across the face back of the nose leaf.

Tail two-thirds the length of the femur and appearing free above the interfemoral membrane. Vibrissæ on muzzle very long. Fur everywhere silky. Above, tips dark brown, the remainder of hair lighter brown. Beneath, lighter in shade, light brown, unicolored. No. 399, Acad. Nat. Sci., is smaller than the specimen named. The length of forearm is 33 mm. (about 1".30), and shorter than that assigned *Chaermycteris minor* Peters. The calcaneum, however, is not as long as the foot. The central incisors are absent in the upper jaw. In other respects the specimen resembles *C. mexicana*. I do not identify this specimen with *C. minor*, but regard it as a variation of *C. mexicana*.

The Skull.—Skull papyraceous; the divisions of the cerebellum and cerebrum discernible through the periphery. Temporal ridge almost *nil*, not forming union at any part of the sagitta. Fronto-maxillary inflation absent, but the inner wall of the orbit and the fronto-nasal depression unite to form a ridge which bears a foramen. Face vertex without median fronto-nasal pit, but in its place a flat surface which bears a median ridge. No groove indicating positions of the nasal bones, but the outlines are seen through the translucent periphery. The sides of the face uniformly convex. The upper border of the anterior nasal aperture incised. The lateral margins of the anterior nasal aperture scarcely produced; the groove between them and the eminence over the canine teeth rudimental. The simple infraorbital foramen over the first premolar tooth.

Alveolar process in height one-thirty-first the width of the neck of the canine and one-thirteenth the vertical diameter of the anterior nasal aperture. Six inconspicuous rugæ. Zygoma incomplete. The infraorbital foramen on same vertical line between the second and third premolars. Hard palate acutely arched in molar range. The posterior border near root of zygoma with slightly convex margin; oval foramen well in advance of the pterygoid free tip which reaches the tympanic bone. The tympanic bone not reaching the postglenoid process. The palatal bone extends to the anterior lacerated foramen before forming the large subacuminate notch. Pterygoid process convex outward, forming bulla-like recesses. The mesopterygoid fossa with a faint vomerine ridge which is continuous with the conspicuous basioccipital ridge. The coracoid process acute, deflected outward, the angle produced beyond the condyloid process, and continuous with the depressed lower border of the masseteric impression. Symphysis with pronounced carination. Brain case, 16 mm. long; face, 14 mm. long; or the face almost as long as the brain case.

The Teeth.—Wide interval between upper incisors. The central as described by Dobson, is smaller than the lateral. But in two specimens examined by me the centrals were larger than the laterals. Both teeth are inconspicuous and scarcely raised above the gum line. The palatal surface of the slender canine flat. Of the two premolars present, the first possesses both anterior and posterior cingules and without increase of width back of the cusp. The second is without posterior cingule, but is widened back of the cusp. The first molar with paracone extending the entire length of the tooth, but sloping from before backward. Protocone and mesocone without buccal fluting or palatal ridges. The second molar as the first, but the protocone ends at the beginning of the mesocone. The third molar as the second much smaller and all parts rudimental.

The lower incisors deciduous. The slender canine with rudimental lingual cingule which does not extend beyond the level of the lateral incisor. The first premolar close to canine with cingule subequal to the cusp. The second and third premolars with cusp much larger than the prominent cingules. The first molar with protocone and paracone almost coalesced; the protocone well advanced. The posterior border of the tooth is furnished with a prominent cingule apparently developed from the hypocone. The first molar is separate from the third premolar and the second and third from one another.

Chaernycteris exhibits vertical muscle fibres in the endopatagium, the nerve markings of the interdigital spaces and the shapes of the terminal cartilage of the fourth digit in a manner quite the same as in *Glossophaga*, though the structure last named is less spatulate than in that genus.

Measurements.—The first phalanx of the first digit shorter than the metacarpal; no phalanx is present in the second digit. The metatarsi and the first row of phalanges equal.

Tongue attached to floor of mouth at the level of the space between the second and the third molars, or 12 mm. from the symphysis. Penis not pendulous.

ANURA.

Interfemoral membrane hairy; tail absent; wing membrane attached to midtarsus; calcar absent; no phalanx to second digit; two warts on upper lip; groove in lower lip wide with many warts. First premolar large remote from canine.

Dental formula: $i. \frac{4}{4} - c. \frac{1}{1} - prm. \frac{3}{3} - m. \frac{3}{3} = 22$.

Resemblance to *Lonchoglossa* very close. The general appearance the same even to the shape of the terminal cartilages of the phalanges. Skull and number of the teeth the same. But it is held that the tail, calcar and phalanx to the second digit all being absent, separate *Anura* from the genus just named.

The first lower premolar possesses a small, anterior, basal cusp and is, therefore, almost as large as the other premolars. The main cusp throughout scarcely higher than the basal cusp.

Anura wiedii Peters.

Auricle much the same as in *Lonchoglossa*. The tip of the tragus is pointed. Nose leaf simple, acuminate, no depression above nostrils. The gland mass at the side of the nostril continuous with that extending up to the side of the nose leaf. Upper lip with two equidistant warts. Fur everywhere long and silky. Above, apical third dark brown, basal two-thirds Isabella brown. Below, apical third Isabella brown; basal two-thirds dark gray. Thus the arrangement of color is boldly contrasted with that of other forms in the group. Fleshy mass of forearm, the interfemoral membrane, the thigh and the feet covered with short hair. On the ventral aspect the forearm is covered with fur which extends thence a short distance on the interfemoral membrane.

The proportions of the wing of *Anura* are those of a larger animal than *Lonchoglossa*, though the thumb is of the same size. The lower extremities are almost identically the same in size, the calcar alone being larger in *Lonchoglossa*. The absence of the phalanx has already been noted in *Chaermycteris*. Alliance with this genus is suggested in the great width of the cleft in the lower lip and in the possession of warts on the upper lip.

The muscle fascicles and membrane markings are as in *Glossophaga*, but the terminal cartilages of the fourth digital interspace while spatulate exhibit the limb on the somad side greatly prolonged. This character is not seen elsewhere in the group. The cartilage of the fifth digit while terete is also greatly prolonged on the free margin of the endopatagium. These characters indicate that there is more strain on the wing during flight than in any other genus.

The Skull.—The skull is almost identical with that of *Lonchoglossa*. The alveolar height is one-third the width of the neck of the canine and one-seventh the vertical diameter of the anterior nasal aperture. The zygoma by careful maceration is shown to be cartilaginous. A specimen of *Lonchoglossa* shows the same structure. The skull is 24 mm. long. The brain case is 60 mm. long, and the face 40 mm. The lower border of the masseteric impression is not produced. Dobson's figure, Pl. XXVII, Fig. 4, does not agree in all respects with our example.

In 1830, Rengger (*Naturgesch. der Säugeth. von Paraguay*, 80) described a species of bat under the name *Glossophaga villosa*. Since Wagner (*Suppl. Schreb. Säugeth.*) assigns this form a place under *Chaermycteris*, it is well to state that while *G. villosa* Rengger retains three premolars in both jaws, that the tail is absent, the interfemoral

membrane is but half an inch deep at the rump, and the lateral upper incisors are smaller than the centrals. The interfemoral membrane is hairy. This species is nearer *Anura* in most of its characters than any other genus in the group.

LONCHOGLOSSA.

Tail short; wing membrane attached to ankle; calcar present but small, about one-third the length of the tibia; a phalanx to second digit; groove in lower lip narrow with a few inconspicuous warts; no warts on upper lip; basal part of nose leaf rudimental; apical third of tongue filamentose; interfemoral membrane not hairy.

Dental formula: $i. \frac{4}{4} - c. \frac{1}{1} - p. \frac{3}{3} - m. \frac{3}{3} = 22$.

The first lower premolar small and without anterior, basal cusp; the main cusps of the entire series twice the height of the basal cusps.

The presence of the tail and a phalanx to the second digit are sufficient grounds to separate *Lonchoglossa* from *Anura*.

Lonchoglossa caudifera Geoff.

Auricle pointed, internal basal lobe bound down to head. External border faintly sinuate scarcely; any external basal lobe; the inner lappet large. Tragus blunt at tip. Nose leaf simple, without pedicle; lateral gland mass of base rudimental; upper lip short, without warts.

Large numerous vibrissæ from face, especially from mentum. Filaments on tongue large, not meeting in middle line of dorsum. Wing membrane reaches to calcar. Seven rugæ on the hard palate, the last two alone divided. The tail not quite as long as the short interfemoral membrane, the tip not free.

The hair of the dorsum exhibits apical third brown, basal two-thirds pallid. Beneath paler, prevailing hue brown (but with scarcely a contrasted shade toward base), tending to become grayer, almost unicolored on loin. Limbs naked.

The wing markings both in the nerves and muscle fascicles are as in *Glossophaga*, but the terminal cartilage of the fourth digit is terete, and that of the fifth digit is small and scarcely deflected.

The Skull.—The bones very thin, permitting the subdivisions both of cerebellum and cerebrum to be seen through the periphery. The pretemporal ridge unites with its fellow at the anterior fourth to form a faint, linear crest; the mesotemporal and posttemporal ridges not separately defined, scarcely discernible. Fronto-maxillary inflation small. Face vertex without pit at the fronto-nasal region; outlines of nasal bones not defined. Side of face convex. The lateral borders of the anterior nasal aperture moderately produced. The foramina between the two premaxillæ near the incisor margin large.

The alveolar process so slender that it cannot be measured. The parts as viewed from in front embrace the floor of the nasal chambers at the premaxillary part and permit the median foramen to be seen. The zygoma without a trace of ascending process. The posterior palatal margin near the root of zygoma spinose; the posterior palatal notch with conspicuous spines. Pterygoid process almost reaching tympanic bone and extends beyond the oval foramen. Mastoid process aciculate. Mesopterygoid fossa with inconspicuous vomerine spine. Basisoccipital depressions shallow. The coronoid process scarcely raised above the level of the condyloid process. The deflected hamular angle projects in a marked degree beyond the condyloid. The lower border of the masseteric impression is produced conspicuously beyond the border of the ramus. Symphysis with large keel. One skull 21 mm. long; face 8 mm. long; brain case 15 mm. long.

Upper Teeth.—The small central incisors separated by wide interval, and each tooth in close contact with the large lateral. The central incisor with ovoid crown scarcely wider than neck; the lateral incisor projecting below the level of the central with crown wider than neck and conspicuously oblique outer border. The interval between lateral incisor and the canine no greater than in other genera. Canine with inner surface flat. First premolar one-half the size of the others; separated from the canine and the second premolar, but nearer the last-named tooth. The second and third premolar triangular, with large basal cingules.

The W-pattern of the molars discernible. In one specimen the long, sloping protocone with suggestion of hypocone, recalling the parts as in *Macrotus*; in the second the teeth were without hypocone. Canine with rudimental heel. First premolar separate from the canine and second premolar. Second premolar separate from the first and third; third premolar separate from the second, but contiguous to the first molar. First molar with cingule of the protocone extended forward, scarcely deflected inward and overlapping third premolar; protocone and paracone approximate, united at base.

Lower Teeth.—First lower premolar without anterior basal cusp, and is, therefore, much smaller than the other premolars. In the entire series of premolars the main cusp is twice as high as the height of the basal cusps. The first and second molars of the same plan with the foregoing, the third being slightly the smaller.

The lower teeth with jaw are figured by Leche (*l. c.*, Taf. II, Fig. 8). The first premolar is represented as being exactly like others of the series. This character would prevent the *Lonchoglossa* of Leche's identification being received under *Lonchoglossa caudifera* of this essay.

Variations.—The above description is based on two specimens, which were subject to some variation. In one the pretemporal crests did not unite. In one the cusps of the teeth were much worn.

Notes on the Skeleton.—Ribs thirteen; first costal cartilage not wider than the rib. Humerus with pectoral crest relatively high, one-half the diameter of distal end of bone. The sternal crest after careful removal of the pectorals is very high and apparently without notch, but the greater part of the interpectoral septum is membranous. The phalanx of the second digit about as in *Vespertilio*. The metatarsi and first row of phalanges of toes equal.

Measurements.—Forearm, 36 mm.; foot and thumb of same length, viz., 8 mm.; forearm, 1.35 mm.

BRACHYPHYLLINA.

I propose to establish the Brachyphyllina to include the genera *Brachyphylla*, and *Phyllonycteris*,* forms which have hitherto been assigned separate groups in the Phyllostomidæ, the first named to the Stenodermata and the second to the Glossophagina.

Brachyphyllina.

Leaf-nosed bats with tip of tongue retaining clump of papillæ extending across dorsum. In the Glossophagina the papillæ are arranged not only at the tip but the sides for great lengths. The minute first upper premolar wedged in between the canine and large second premolar; coronoid process acute, raised high above the level of the condyloid process. Mesopterygoid fossa deep, apex answers to the junction of the anterior and middle third of the zygoma. Nasal bones high, arched, defining a depression between them and the maxilla. Sagitta entire with well-defined pretemporal crests. The glands of muzzle continuous behind nose leaf. Thumb large, one-fourth the length of the forearm, nearly. Auricle narrow, oval with pointed tip. Tragus coarsely serrate entire length of outer border. Upper lip hairy, without warts. Lower lip with shallow median groove, margined with large warts. Lips not fringed internally.

BRACHYPHYLLA.

Upper central incisors very much larger than the laterals. Length of forearm, 65 mm.; that of thumb, 16 mm., this being about one-fourth the length of the forearm as in *Phyllonycteris*. Grinding surfaces of molars with numerous large mammillations, cuspidation distinct. Angle of lower jaw quadrate, massive; nostril entire, the wide outer margin and the side of the rudimental nose leaf continuous. Tragus entire on inner border. The tail rudimental, one-fourth the length of tibia, and concealed in the interfemoral membrane.

Dental formula: i. $\frac{4}{4}$ — c. $\frac{1}{1}$ — prm. $\frac{2}{2}$ — m. $\frac{3}{3}$ = 20.

* I have not studied *Rhinophylla*, but the conclusions arrived at after reading the accounts of Peters and Dobson induce me to place the genus in the same alliance with genera just named. But in the absence of material I am compelled to confine my comparisons to *Brachyphylla* and *Phyllonycteris*.

Brachyphylla cavernarum Gray.

The auricle lanceolate with slightly convex margins, basal lobes rudimental. The tragus pointed, one-half the length of the inner margin of the auricle; convex on thickened inner, and coarsely serrate on outer, margin.

Nose leaf with entire nostrils and wide ectonareal flange; erect portion of nose leaf rudimental—concave and often minutely crenulate on midmargin. Supranarial margin concave on either side of an obscure median ridge. Infranarial margin wide, continuous with upper lip and faintly incised. The basal gland-clump continuous across face—vertex back of nose leaf. The upper and outer parts are thick and bear a few coarse bristles, while the lower are thin and lost on the upper lip. Twelve warts are arranged in pairs on the side of a mental V-shaped group, the median groove being shallow. Two median warts may be said to have slight morphological significance.

The fur above is yellowish white except the tip, which is brown. Below the tints are the same, but the shaft is more tawny and the tips much lighter. The distal third of the arm above and below is covered with hair. The distal half of the thigh is similarly covered. A sparse growth of hair is limited to the upper half of the dorsal surface of the interfemoral membrane.

The calcar is rudimental. The terminal cartilages of the fourth and fifth digits are uniform, elongated and scarcely wider at free margin than on the sides. The second interdigital space is almost devoid of pigment. The third space retains a vertical line for nearly its entire length, while the fourth exhibits one for about an inch near the free margin, the rest of the space being areolated. The endopatagium is furnished with numerous thick muscle fascicles; near the tibia it is thick and leathery.

Pteral formula:	Second interspace,	Third interspace,	Fourth interspace,
	3 mm.	19 mm.	35 mm.

The Skull.—The walls of the skull are thin and permit the divisions of the brain to be discerned. The sagittal, pretemporal and occipital crests are well defined and trenchant. The fronto-maxillary inflation is conspicuous and bears the pretemporal crest. The inner orbital wall is moderately convex, and is marked by a conspicuous foramen. The infraorbital foramen is placed well in advance of the orbit in line of the second premolar. The zygoma with a rudimental ascending process at the posterior third, but none anteriorly to contribute to the limitation of the orbit.

Lower Teeth.—The incisors are stout, in continuous row. The palatal basal cusp is on level with the crown, which thus presents a broad, quadrate surface, marked in the middle from before backward by a ridge. Canine without conspicuous basal cusp. Premolars subequal, the first the smaller and triangular, the second with large basal cusp.

First and second molars with quadritubercular cusps well defined, a large mammillation on the anterior commissure of the second molar; the third molar triangular, tritubercular.

Upper Teeth.—The central incisors are very large, triangular, nearly filling the interval between the canines. The lateral incisors are minute, not over one-fourth the size of the centrals. The anterior surface is concave; the crown is blunt and quadrate, with basal cusp and cutting edge equal. The canine with anterior and posterior denticles, the posterior of the two being enormous and presenting the aspect of being an outshoot from the side of the crown. The first premolar minute and of the same form as the lateral incisor. The second premolar large, triangular and projecting beyond the molars. The basal cusp (denterocone) conspicuous. Molars tritubercular, without W-shaped pattern. Several mammillations are present on the grinding surfaces. Third molar is one-half the size of the second.

Measurements of Brachyphylla cavernarum.

	Millimeters.
Head and body (from crown of head to base of tail).....	66
Length of arm.....	40
Length of forearm.....	65
First digit:	
Length of first metacarpal bone.....	4
Length of phalanges.....	12
Second digit:	
Length of second metacarpal bone.....	46
Length of first phalanx.....	5
Third digit:	
Length of third metacarpal bone.....	55
Length of first phalanx.....	17
Length of second phalanx.....	23
Length of third phalanx.....	11
Fourth digit:	
Length of fourth metacarpal bone.....	51
Length of first phalanx.....	15
Length of second phalanx.....	17
Fifth digit:	
Length of fifth metacarpal bone.....	55
Length of first phalanx.....	15
Length of second phalanx.....	14
Length of head.....	34
Height of ear.....	12
Height of tragus.....	9
Length of thigh.....	23
Length of tibia.....	27
Length of foot.....	29
Length of interfemoral membrane.....	21
Length of tail.....	7

PHYLLONYCTERIS.

Upper incisors separated from the laterals by wide intervals; naked skin-fold defining nostrils laterally; nose leaf not reaching above the level of approximate club-shaped gland masses. Thumb the largest in the group nearly one-fourth the length of the forearm. Length of forearm, 45 mm. Teeth with cusps nearly obliterated, no W-pattern on molars. Large vacuity between occipital bone and pars-squamosal of the temporal. Fimbriæ not arranged in rows, but form a uniform covering to the tip of the tongue. The first and fifth metatarsal bones longest. The first row of phalanges of third to fifth digit of manus, same length as the second row. Calcar wanting. Zygomatic arches fibro-cartilaginous.

Dental formula : i. $\frac{4}{4}$ — c. $\frac{1}{1}$ — prm. $\frac{2}{3}$ — m. $\frac{3}{3}$ = 21.

Phyllonycteris was described by Gundlach, but published under the care of Peters, who does not appear to have known the form. Gundlach correctly compares the genus to *Brachyphylla*. Dobson follows Gundlach closely, his description being little more than a translation of the original article. When he departs from the text he makes statements which do not agree with the specimen on which the present essay is based. Thus he says, "the incisors are as in *Glossophaga*; the molars like those of *Carollia* (*Hemiderma*), but the W-shaped cusps scarcely developed;" whereas the upper lateral incisor is twice the size of the central and the zygoma may be complete. With the exception of the skulls, Dobson did not study *Phyllonycteris* at first hand.

Phyllonycteris sezeicorni Gundl.

Auricle simple, ovate, with rounded pointed tip. External outline without subdivision or inner lappet near the base. Internal basal lobe scarcely free. Tragus convex on inner side, straight on outer. Both sides marked by three, coarse, teeth-like processes. Basal point scarcely longer.

Nose leaf simple, obtuse with internarial pedicle. The perinarial flange is lamellar and distinct from gland mass. The structure last named well defined, apparently crossing muzzle back of the nose leaf, but two club-shaped masses are nearly approximate. Upper lip high without warts. Interfemoral membrane deeply incised, extending from distal third of the tail to the calcaneum. The tail is short, scarcely projecting beyond the interfemoral membrane. The fur long and silky above, light gray tipped, subtip sooty, the rest of the hair pale verging to white. Beneath much paler, nearly uniform gray. The tip of hair tawny, the rest of the hair of a somewhat lighter shade.

Almost the entire field of the endopatagium filled with widely separated nearly equidistant vertical muscle fascicles. There is no reticulated arrangement of fibres. The

nerve markings in the fourth interspace as in *Glossophaga* except that from the fourth digit there are three instead of one nerve. The terminal cartilage of the fourth digit is obscurely spatulate.

The Skull.—The skull not papyraceous, the division of the cerebellum, but not of the cerebrum, discernible on periphery. The pretemporal crest distinct. It begins over the moderate fronto-maxillary inflation to form a delicate crest by union with the fellow of the opposite side at the anterior third of the sagitta. Mesotemporal and posttemporal crests not discerned. The orbital ridge is rudimental, but the frontonasal pit conspicuous at proximal end of the slightly convex nasal bones. The large infraorbital foramen lies over interval between second premolar and first molar and is thatched by a ridge. The alveolus (*i. e.*, the distance from the central incisor to the anterior nasal aperture) equals in height one-fifth of the base of the upper canine and one-eighteenth of the vertical diameter of the large, anterior, nasal aperture. The zygoma often complete.* The maxilla at root of zygoma with a very small ascending process. The premaxilla at the side of the anterior nasal aperture salient. Neither the groove between the nasal bones or the depression on the maxilla at the side of the nasal bones are conspicuous. The depression between the aperture last named and the eminence over the canine is shallow. The hard palate just back of the last molar is sharply defined by a double crescentic transverse ridge; the palatal notch is acute and deep, the apex reaching the level of the anterior third of the zygomatic arch, the pterygoid process corresponding in position to the oval foramen. The tympanic bone touches the postglenoid process. The junction of the ethmoid and sphenoid bones in the brain case not convex. A vacuity is found in the line of junction of occipital and squamosal bones.

The basioccipital bone with scarcely any pit-like depressions; the vomerine ridge scarcely discernible in the mesopterygoid fossa. The mastoid process small, conical. The proportion of the face to the brain case is as 9 to 15 mm.

Lower Jaw.—Coronoid process acuminate. The hamular angle not deflected or projected beyond the condyloid process; lower border of the masseteric impression not distinguished from the corresponding border of the horizontal ramus. Back of the molars and at base of coronoid process a tubercle for insertion of temporal muscle is seen. Symphysis-menti broad, non-carinate, the surface near the incisors marked by coarse venous foramina.

The Teeth.—The upper central incisors hatchet-shaped, contiguous; laterals much smaller, not half the size of centrals and separate therefrom. The incisors not entirely occupying space between the canines. Canine broad at base, robust, convex entire length

* Dobson (*Cat. Chirop. Br. Mus.*) in text states that they are incomplete, but acknowledges the fibro-cartilagium arch in a footnote.

of palatal surface. First premolar very small, nodular, about one-fourth the size of the second and not much larger than the lateral incisor. Second premolar triangular, without basal cusp; posterior half of palatal surface concave. Molars without well-defined cusps and decrease in size gradually from before backward. The third molar one-half the size of the second. The protocone, paracone and metacone scarcely indicated; no W-shaped pattern.*

Lower lateral incisors twice the size of the centrals; all are non-contiguous and nodular. Canine with conspicuous concave heel; all other parts convex; cingulum extends inward so as to lie back of the lateral incisor. The premolars thick and robust, subequal; the first smaller. The molars decreasing in size from before backward without details.

Of the measurements it is noted that the first phalanx of the first digit is scarcely longer than the metacarpal bone. In the second digit the single phalanx is one-tenth the length of the corresponding metacarpal bone. The entire second digit is as long as the third metacarpal bone. In the third digit the first and second phalanges are equal—the third phalanx is nearly one-half the length of the second. The terminal cartilage of the fourth digit is moderately spatulate, and that of the fifth digit is deflected toward the body. The wing membrane attached to the tibia at the distal seventh or to the ankle. Interfemoral membrane attached to tip of the small calcaneum.

The Skeleton.—The sternum is boldly keeled over the presternum and metasternum. The ribs are twelve in number. The first costal cartilage is discoidal. The humeral pectoral crest is relatively low and not half the diameter of the proximal end of the bone. The fifth metatarsal bone is much the largest of the series. Palatal rugæ eight, last three to four interrupted in centre. The first and fifth metatarsals are longer than the others. The bones of the first row of phalanges of the toes are equal.

* Peters and writers following him give all glossophagine genera W-shaped pattern of molars. I have had no opportunity of examining the type of *Phyllonycteris* in the Berlin Museum, but I have received through the kind offices of Mr. Paul Matschie a photograph of the skull which I find conforms to the account above given.

Table of Measurements (in millimeters).

	<i>Glossophaga soricina.</i>	<i>Glossophaga truei.</i>	<i>Leptonycteris nivalis.</i>	<i>Chonycteris mexicana.</i>	<i>Lonchoglossa caudifera.</i>	<i>Anura wiedii.</i>	<i>Phyllonycteris sezecorni.</i>
Head and body (from crown of head to base of tail).....	45	45	57	55	40	42	32
Length of arm.....	19	?		20	20	20	25
Length of forearm.....	36	32	50	42	35	38	45
First digit :							
Length of first metacarpal bone.....	4	4	4	4	3	3	5
Length of first phalanx.....	4	4	4	3	3	3	7
Second digit :							
Length of second metacarpal bone.....	30	25	40	40	29+	33	33
Length of first phalanx.....	1	2	3	0	2	0	3
Third digit :							
Length of third metacarpal bone.....	34	30	47	45	37	38	38
Length of first phalanx.....	13	11	14	17	12	13	14
Length of second phalanx.....	16	12	23	21	18	21	14
Length of third phalanx.....	7	6	8	9	9	11	8
Fourth digit :							
Length of fourth metacarpal bone.....	33	27	42	40	34	37	35
Length of first phalanx.....	10	9	11	12	9	10	13
Length of second phalanx.....	10	9	16	15	12	13	11
Fifth digit :							
Length of fifth metacarpal bone.....	30	27	40	35	30	30	35
Length of first phalanx.....	9	8	10	10	7	8	11
Length of second phalanx.....	9	8	10	13	11	12	10
Length of head.....	23	21	27	32	25	29	25
Height of ear.....	14	11	12	13	13	14	11
Height of tragus.....	4	3	4	5	4	4½	5
Length of thigh.....	10	?	15	15	13	14	19
Length of tibia.....	14	11	20	17	13	13	20
Length of foot.....	8	8	12	10	7	7	13
Length of interfemoral membrane in median line.....	10	9		20	4	6	7
Length of tail.....	5	?		8	4	0	10

NOTE.—The Secretaries deem it proper to state that this, as well as the succeeding paper, was presented to the Society after the author's death, which lamented event occurred on November 14, 1897, and that, therefore, it has not had the benefit of his revision in its passage through the press. †

EXPLANATION OF THE PLATES.

PLATE VI.

- Fig. 1. *Glossophaga soricina*. Head seen from in front. $\times 2$.
 Fig. 2. *Glossophaga soricina*. Skull vertex. $\times 3$.
 Fig. 3. *Glossophaga soricina*. Skull profile. $\times 3$.
 Fig. 4. *Glossophaga soricina*. Skull base. $\times 3$.
 Fig. 5. *Glossophaga soricina*. Jaws with incisors and canines seen from in front. $\times 8$.
 Fig. 6. *Glossophaga soricina*. Upper teeth. $\times 10$.
 Fig. 7. *Glossophaga soricina*. Lower teeth seen from above. $\times 10$.
 Fig. 8. *Glossophaga soricina*. Left lower molars seen in profile from lingual aspect. The first molar is to the right. $\times 10$.

PLATE VII.

- Fig. 9. *Glossophaga truei*. Head seen from in front. $\times 2$.
 Fig. 10. *Glossophaga truei*. Skull vertex. $\times 3$.
 Fig. 11. *Glossophaga truei*. Skull profile. $\times 3$.
 Fig. 12. *Glossophaga truei*. Skull base. $\times 3$.
 Fig. 13. *Glossophaga truei*. Upper teeth. $\times 8$.
 Fig. 14. *Glossophaga truei*. Lower teeth seen from above. $\times 8$.
 Fig. 15. *Glossophaga truei*. Left lower molars seen in profile from lingual aspect. The first molar is to the right. $\times 8$.

PLATE VIII.

- Fig. 16. *Monophyllus redmani*. View of head from in front, showing ear and nose leaf. $\times 2$.
 Fig. 17. *Monophyllus redmani*. Skull of same. Norma verticalis. $\times 3$.
 Fig. 18. *Monophyllus redmani*. Skull of same. Norma lateralis. $\times 3$.
 Fig. 19. *Monophyllus redmani*. Skull of same. Norma basilaris. $\times 3$.
 Fig. 20. *Monophyllus redmani*. Upper and lower jaws seen from in front. $\times 8$.
 Fig. 21. *Monophyllus redmani*. Teeth of the same as seen from the surfaces of crowns. $\times 8$.

PLATE IX.

- Fig. 22. *Brachyphylla cavernarum*. View of head showing ears and nose leaf.
 Fig. 23. *Brachyphylla cavernarum*. Skull of same. Norma verticalis. $\times 3$.
 Fig. 24. *Brachyphylla cavernarum*. Skull of same. Norma lateralis. $\times 3$.
 Fig. 25. *Brachyphylla cavernarum*. Skull of same. Norma basilaris. $\times 3$.
 Fig. 26. *Brachyphylla cavernarum*. Upper and lower jaws seen from in front. $\times 8$.

PLATE X.

- Fig. 27. *Brachyphylla cavernarum*. Teeth of same seen from the surfaces of crowns. $\times 8$.
 Fig. 28 to 39. *Brachyphylla cavernarum*. Terminal cartilages of the fourth and fifth digits.

PLATE XI.

- Fig. 40. *Leptonycteris nivalis*. Head seen from in front. $\times 2$.
 Fig. 41. *Leptonycteris nivalis*. Skull vertex. $\times 3$.
 Fig. 42. *Leptonycteris nivalis*. Skull profile. $\times 3$.
 Fig. 43. *Leptonycteris nivalis*. Skull base. $\times 3$.
 Fig. 44. *Leptonycteris nivalis*. Jaws with incisors and canines seen from in front. $\times 8$.
 Fig. 45. *Leptonycteris nivalis*. Upper teeth. $\times 8$.

Fig. 46. *Leptonycteris nivalis*. Lower teeth. $\times 8$.

Fig. 47. *Leptonycteris nivalis*. Left lower molars seen in profile from lingual aspect. The first molar is to the right. $\times 10$.

PLATE XII.

Fig. 48. *Chærnycteris mexicana*. Head seen from in front. $\times 2$.

Fig. 49. *Chærnycteris mexicana*. Skull vertex. $\times 3$.

Fig. 50. *Chærnycteris mexicana*. Skull profile. $\times 3$.

Fig. 51. *Chærnycteris mexicana*. Skull base. $\times 3$.

Fig. 52. *Chærnycteris mexicana*. Jaws with incisors and canines seen from in front. $\times 8$.

Fig. 53. *Chærnycteris mexicana*. Upper teeth. $\times 10$.

Fig. 54. *Chærnycteris mexicana*. Lower teeth. $\times 10$.

Fig. 55. *Chærnycteris mexicana*. Left lower molars seen in profile from lingual aspect. The first molar is to the right. $\times 10$.

PLATE XIII.

Fig. 56. *Lonchoglossa caudifera*. Head seen from in front. $\times 2$.

Fig. 57. *Lonchoglossa caudifera*. Skull vertex. $\times 3$.

Fig. 58. *Lonchoglossa caudifera*. Skull profile. $\times 3$.

Fig. 59. *Lonchoglossa caudifera*. Skull base. $\times 3$.

Fig. 60. *Lonchoglossa caudifera*. Jaws with incisors and canines seen from in front. $\times 8$.

Fig. 61. *Lonchoglossa caudifera*. Upper teeth. $\times 8$.

Fig. 62. *Lonchoglossa caudifera*. Lower teeth. $\times 8$.

Fig. 63. *Lonchoglossa caudifera*. First and second right lower molars seen from lingual aspect. The first tooth is to the right. $\times 10$.

PLATE XIV.

Fig. 64. *Anura wiedii*. Head seen from in front. $\times 2$.

Fig. 65. *Anura wiedii*. Skull vertex. $\times 3$.

Fig. 66. *Anura wiedii*. Skull profile. $\times 3$.

Fig. 67. *Anura wiedii*. Skull base. $\times 3$.

Fig. 68. *Anura wiedii*. Jaws seen from in front showing incisors and canines. $\times 8$.

Fig. 69. *Anura wiedii*. Upper teeth. $\times 8$.

Fig. 70. *Anura wiedii*. Lower teeth. $\times 8$.

Fig. 71. *Anura wiedii*. Left lower molars seen from lingual aspect. The first tooth is to the right. $\times 10$.

PLATE XV.

Fig. 72. *Phyllonycteris sezeccorni*. Head from in front. $\times 2$.

Fig. 73. *Phyllonycteris sezeccorni*. Skull vertex. $\times 3$.

Fig. 74. *Phyllonycteris sezeccorni*. Skull profile. $\times 3$.

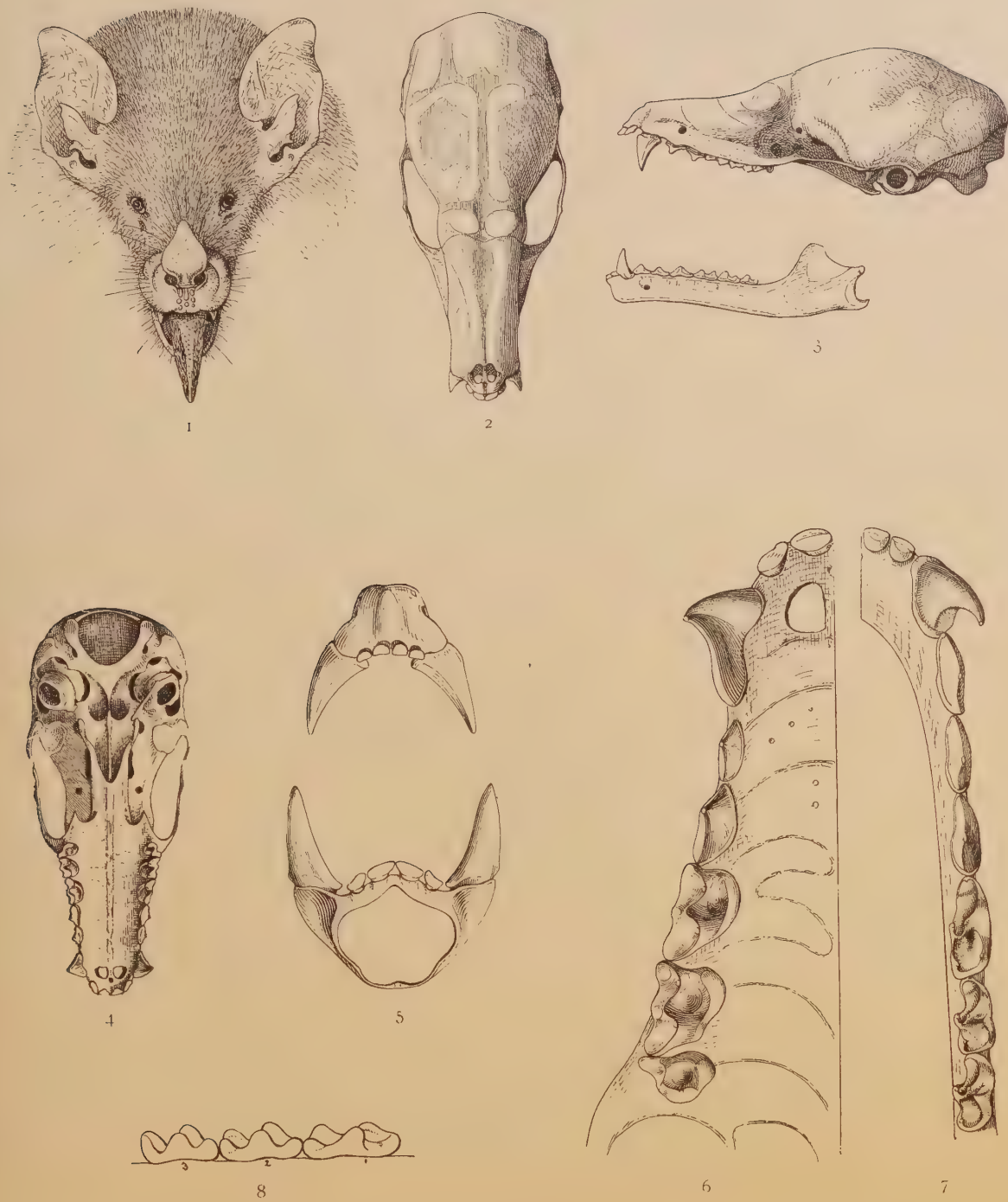
Fig. 75. *Phyllonycteris sezeccorni*. Skull base. $\times 3$.

Fig. 76. *Phyllonycteris sezeccorni*. Upper teeth. $\times 10$.

Fig. 77. *Phyllonycteris sezeccorni*. Lower teeth. $\times 10$.

Fig. 78. *Phyllonycteris sezeccorni*. Jaws seen from in front showing incisors and canines. $\times 8$.

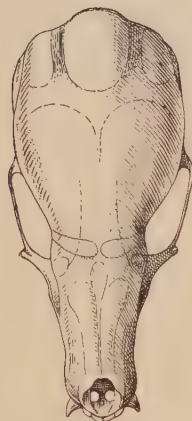
Fig. 79. *Phyllonycteris sezeccorni*. Left lower molars seen from lingual aspect. The first tooth is to the right. $\times 10$.



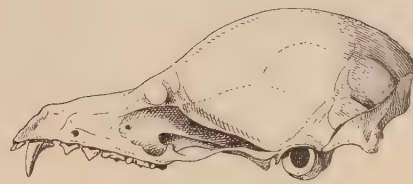
GLOSSOPHAGA SORICINA.



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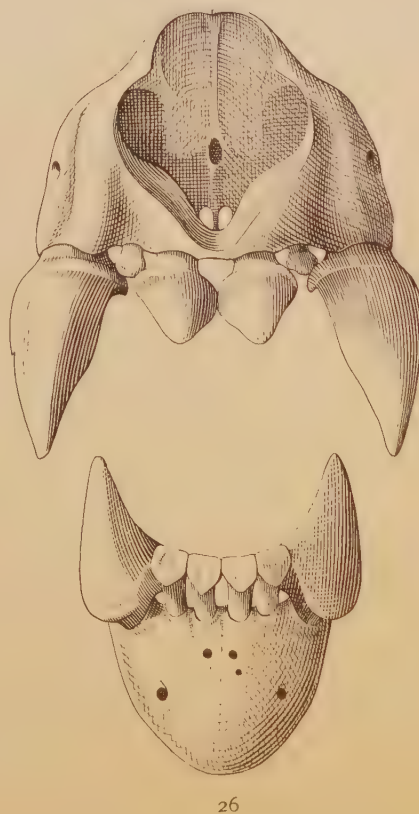
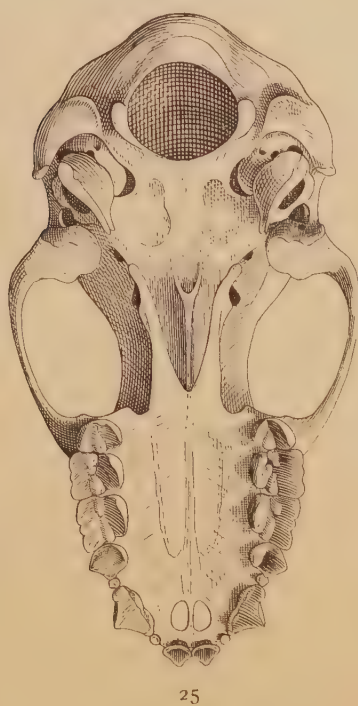
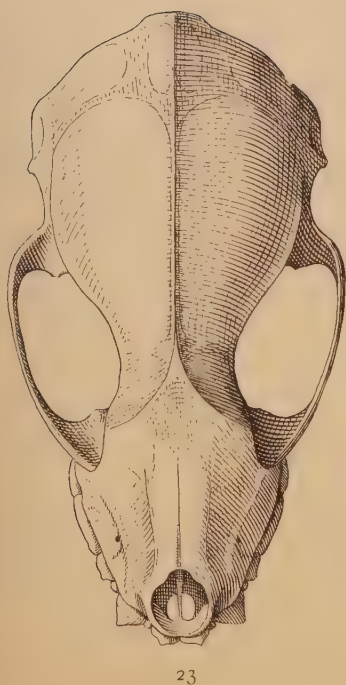
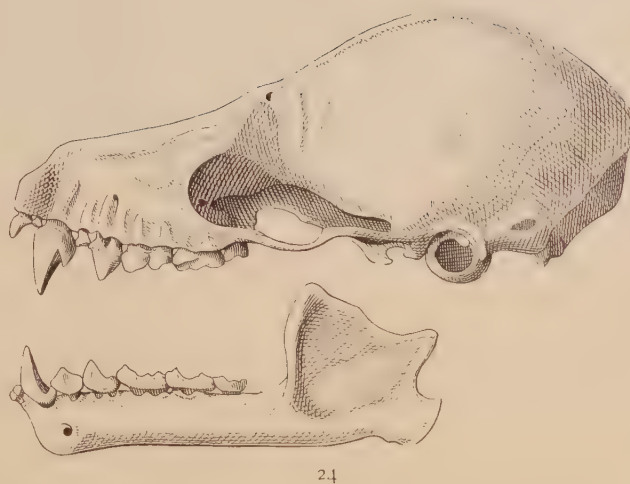


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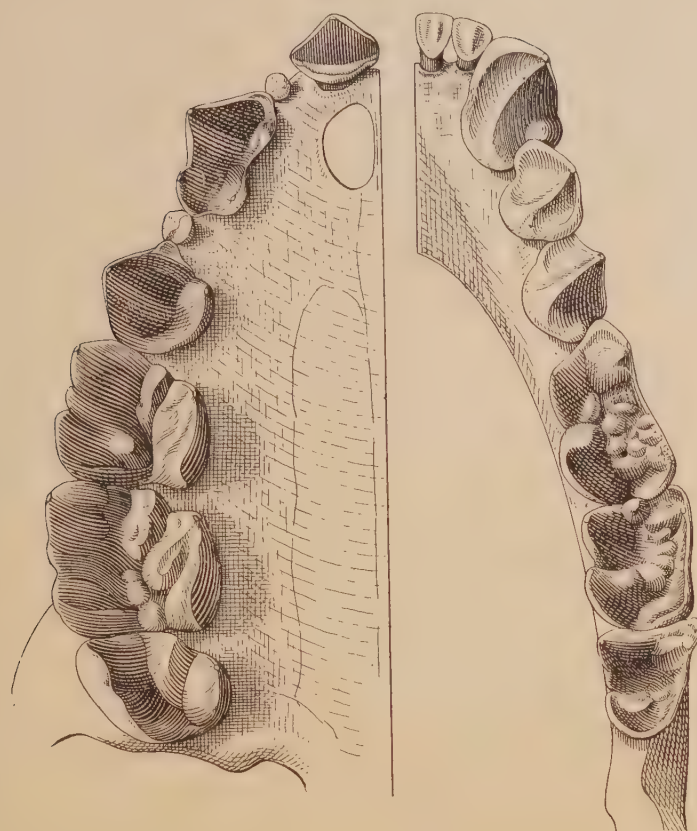
GLOSSOPHAGA TRUEL.



MONOPHYLLUS REDMANI.



BRACHYPHYLLA CAVERNARUM.



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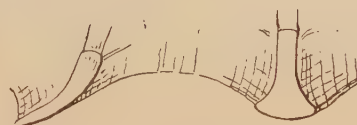
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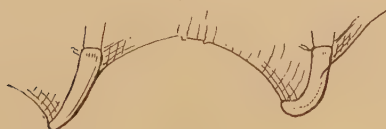
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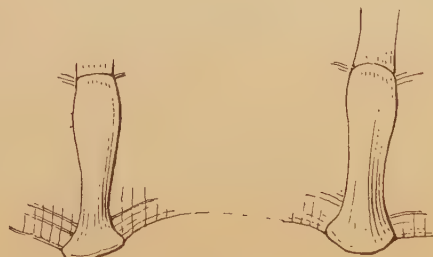
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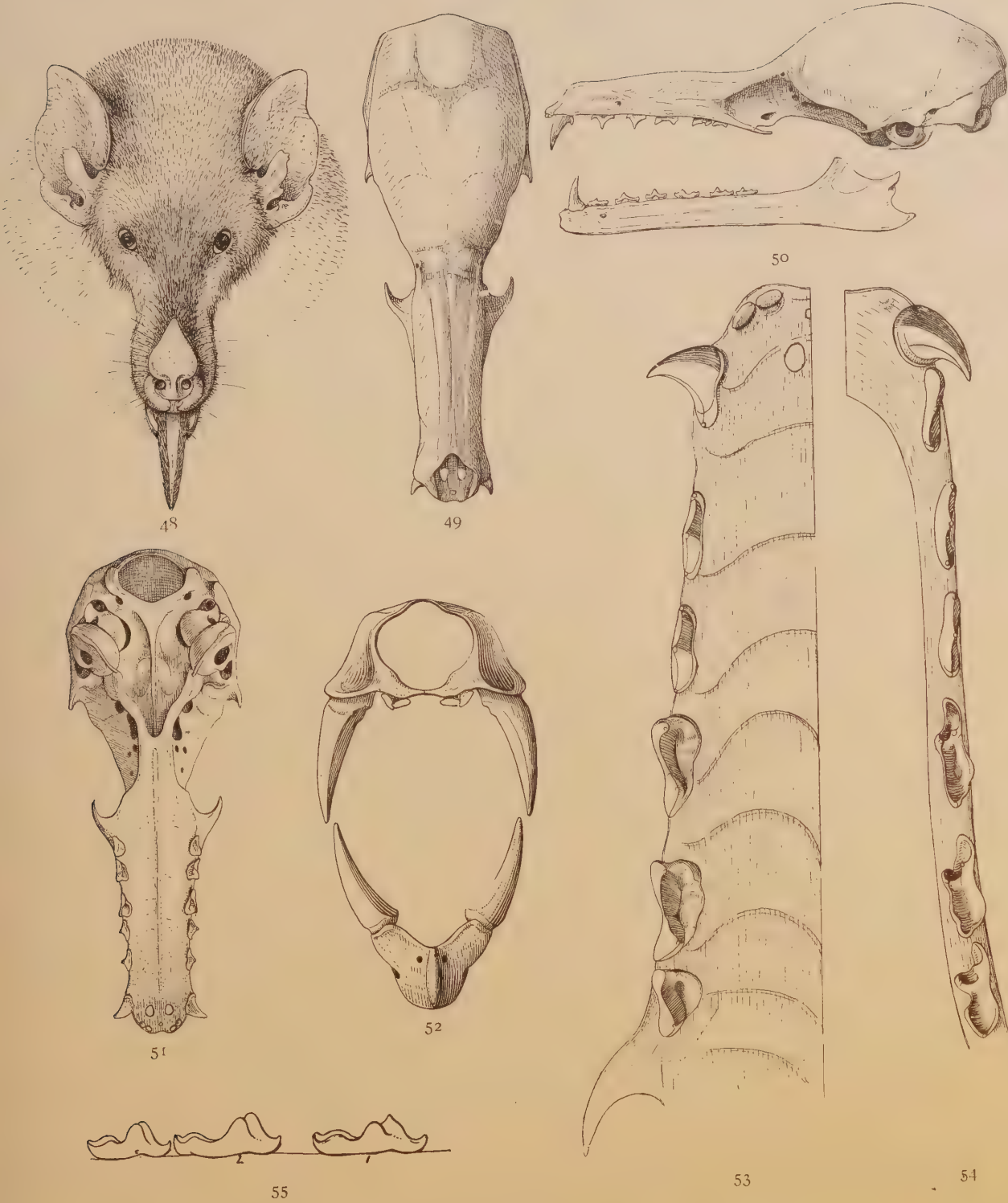


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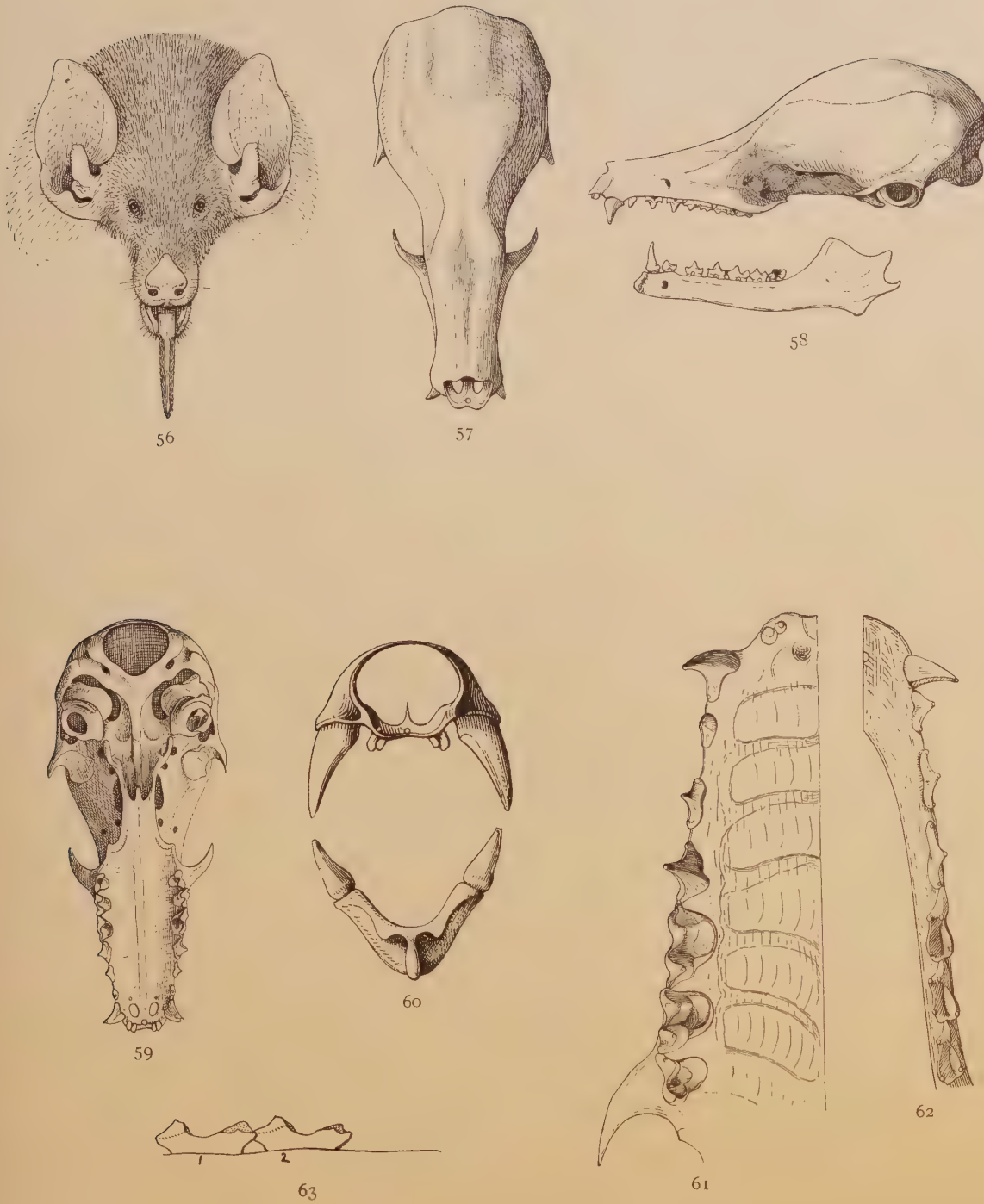
BRACHYPHYLLA CAVERNARUM.



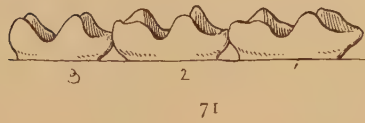
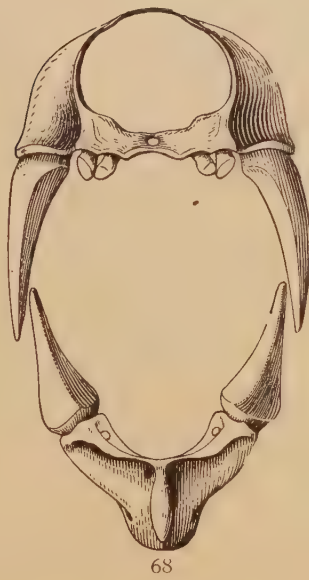
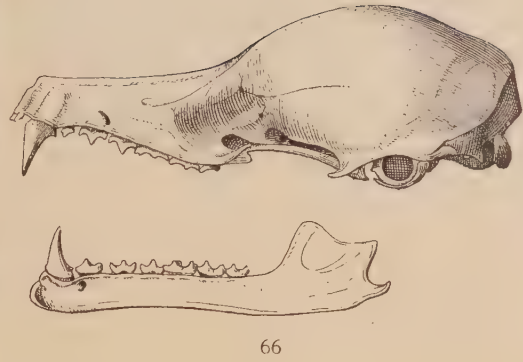
LEPTONYCTERIS NIVALIS.



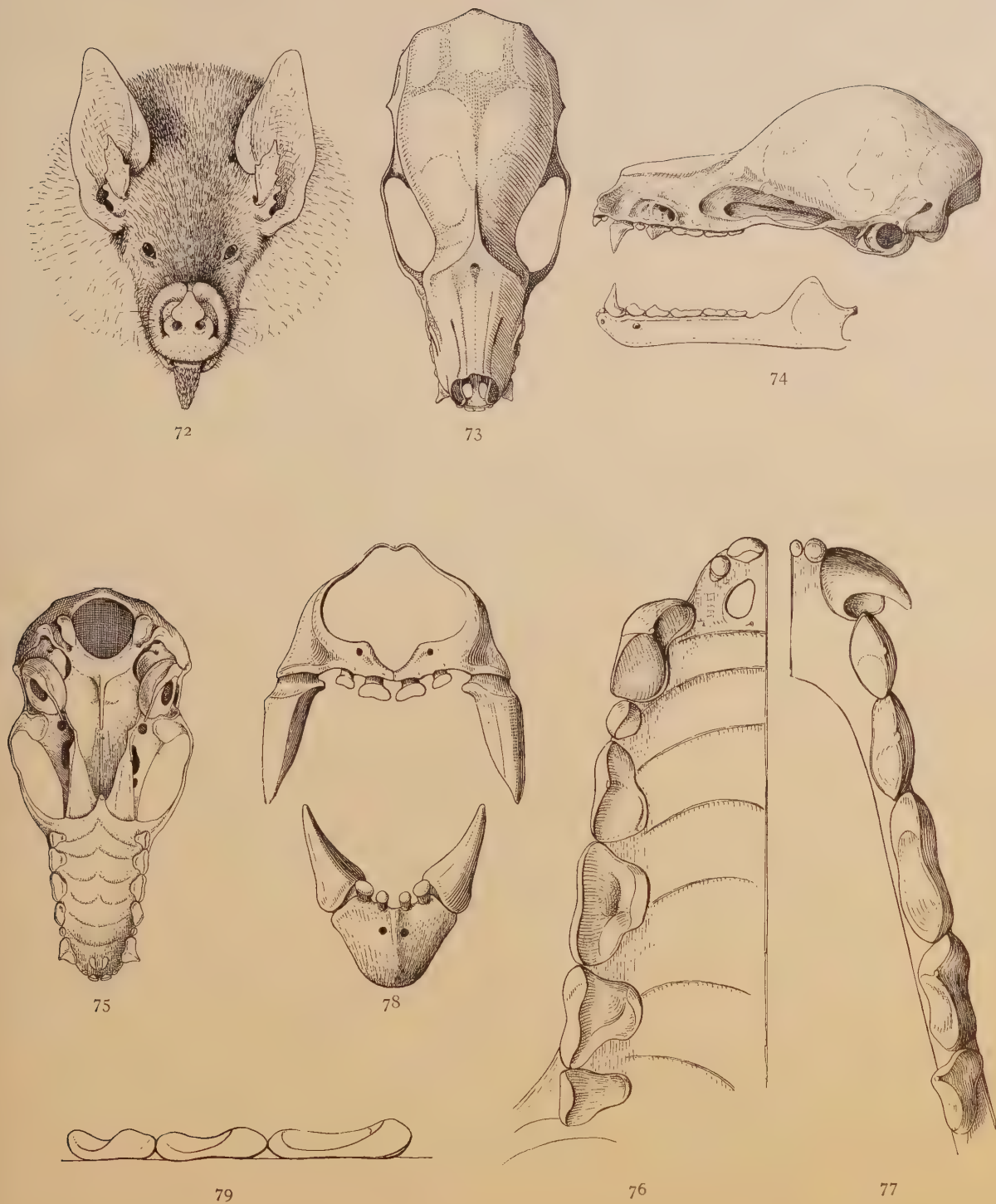
CHÆRONYCTERIS MEXICANA.



LONCHOGLOSSA CAUDIFERA.



ANURA WIEDII.



PHYLLONYCTERIS SEZECORNI.

ARTICLE VI.

THE SKULL AND TEETH OF ECTOPHYLLA ALBA.

(Plate XVI.)

BY HARRISON ALLEN, M.D.

Read before the American Philosophical Society, January 21, 1898.

In 1892 (*Proc. U. S. Nat. Mus.*, 1892, No. 913, 441), I described a bat from Honduras under the name of *Ectophylla alba*. The single specimen was without skull. I have been permitted through the courtesy of Mr. Oldfield Thomas, of the British Museum, to inspect a second example of the genus. The material consisted of a dried skin and a skull of a male individual which was mutilated by shot in the pterygoid and orbital regions. The specimen was collected at San Emilio, Lake Nic-Nac, Nicaragua.*

The *norma verticalis* shows faint fronto-temporal lines which barely approximate near the bregma, but recede from that point posteriorly so that no trace of a temporal crest exists. The fronto-maxillary inflation is conspicuous and makes a swollen border for the upper and anterior orbital margins. The nasal bones are sharply elevated above the plane of the maxilla. Sufficient of the *norma basilaris* remains intact to show that the hard palate is elongated and the palatal bones are produced, thus separating the genus sharply from *Stenoderma* and its allies and allying it to *Vampyrops* (see Synoptical Key). The basioccipital bone is deeply pitted for muscular impressions. In this respect it presents a marked contrast with *Vampyrops*, in which this bone is nearly flat. The tympanic bone is small, leaving the greater part of the cochlea exposed. The *norma occipitalis* shows a weak occipital ridge. The junction of the ectopetrosal † surface of the pars-petrosa with the occipital bone is complete, while in *Vampyrops* a vacuity exists.

The lower jaw retains a curved aciculate angle relatively twice the size of the same

* The skin was badly mutilated by shot and the nose leaf and chin plates so distorted that no attempt is made to compare the parts with the original description. The second interdigital space is without pigment, head and neck both above and below are pure white. The lower third of the body both on dorsum and ventre is tipped with ash-gray.

† I propose naming that part of the pars-petrosa lying in the brain case the endopetrosal, and that lying exposed back of the pars-squamosa the ectopetrosal part (*Journ. Acad. Nat. Sci.*, 1896, Philadelphia).

part in *Vampyrops*. The masseteric muscle extends to the lower margin of the ascending ramus. The coronoid process is one-third smaller than in the genus last named.

Dental formula: i. $\frac{2}{2}$ — c. $\frac{1}{1}$ — prm. $\frac{2}{2}$ — m. $\frac{2}{2} \times 2 = 28$.

The Teeth.—Upper incisors conical; the centrals larger than the laterals with relatively broader bases. The centrals are separated from each other by a smaller interval than exists between these teeth and the laterals, or between the teeth last named and the canines. The canines are slender and slightly longer than the second premolar. The first premolar is pointed, root much exposed and is about one-third the size of the second. The first upper molar is quadrate with trenchant marginal cusps in position of protocone, paracone and metacone; the crown defined by these elements is concave. The second molar is pyriform, the base being toward the palate. A pointed marginal cusp is seen in the position of the paracone and a second in that of the metacone. The crown is concave and simple, save for a longitudinal ridge. The premolars and molars are separate from one another; the greatest interval being between the premolars.

The lower incisors are blunt cones, contiguous, filling space between canines; the teeth last named are deeply excavate posteriorly. Premolars are aciculate, the first tooth almost touching the canine and is smaller than second. The second tooth is deeply concave posteriorly with a conspicuous heel and cusp. The molars are subequal, without W-pattern. The first molar is obscurely quadrate, slightly narrowed in front with enormous sharply pointed paraconid; other cusps are absent; the lingual border is not raised. The second molar is subrounded, no trace of cusps being present other than a longitudinal ridge in the middle of the deeply excavate crown. The front and lingual borders of the tooth are greatly elevated, the former furnished with two sharp processes, the latter crenulate. The teeth are all separated from one another beyond the canine, the smallest interval being that between the canine and the first premolar and the widest between the premolars.

Ectophylla is in alliance with *Vampyrops*. It resembles this genus in the upper incisors and first upper premolar being conical and in the prolongation of the palatal bones. The shape of the lower first molar possesses a large paraconid, but is without protoconid. In the dental characters last named *Ectophylla* is like all other *Stenoderminæ*, excepting *Brachyphylla*, *Artibeus*, *Dermanura* and *Sturnira*.

The forms exhibiting the stunted, first, lower molar are again divided into two groups by the palate and the lower jaw. In *Chiroderma*, *Vampyrops* and *Ectophylla* the palate is oblong; the palate bone extends to a point answering to the anterior root of the zygoma, or even the posterior third of the arch, and the lower jaw has a well-defined posterior border to the ascending ramus, with no deflected angle. In *Pygoderma*, *Stenoderma* and

Trichocorys, the palate is rounded, as a rule excavated and rarely reaches a point answering to the anterior root of the zygoma; the lower jaw has no well-defined posterior border, the boldly deflected angle almost reaching the condyloid process.

The position of *Ectophylla* in the Stenoderminæ is shown in the synoptical natural key. *Brachyphylla* is an annectant genus to the Glossophagina through *Phyllonycteris*. *Artibeus*, *Dermanura* and *Sturnira* apparently relate to the Vampyri, but while the structure of the molars is essentially that of this group, no annectant form is known. *Sturnira* in the simplicity of the tooth structure recalls *Hemiderma*. The relation between the remaining genera of the table is intimate. The Stenoderminæ constitute, with the exception of the Heamatophilina, the most aberrant group of the Phyllostomididæ.

I recognize, therefore, the following natural arrangement of the genera :

Subfamily STENODERMATINÆ.

Brachyphyllini.....	<i>Brachyphylla</i> .
Artibeini.....	{ <i>Artibeus</i> . <i>Uroderma</i> . <i>Dermanura</i> . <i>Sturnira</i> .
Chirodermini *.....	{ <i>Chiroderma</i> . <i>Vampyrops</i> . <i>Ectophylla</i> .
Stenodermini.....	{ <i>Stenoderma</i> . <i>Pygoderma</i> . <i>Centurio</i> . <i>Trichocorys</i> . <i>Ametrida</i> . <i>Sphæronycteris</i> .

A Natural Synoptical Key of the Stenodermidæ, Based on Characters Derived from the Skull and Teeth.

I. First lower molar elongate with paraconid distinct.

Group Brachyphyllini....	{ a. Angle of lower jaw broad, scarcely pointed, concave above, not deflected, ascending ramus defined. Hard palate oblong, palatal bones produced. Upper incisors conical, molars $\frac{2}{3}$; crowns coarsely ridged; all cusps of the first lower molar subequal... <i>Brachyphylla</i> .
--------------------------	--

* *Chiroderma* is not as near *Vampyrops* and *Ectophylla* as the members of other groups are to each other.

Group Artibeini.....	a'. Angle of lower jaw narrow, aciculate, not deflected ; posterior border of ascending ramus defined ; hard palate oblong ; palate produced.
	b. Palatal bones extend to point answering to the middle of zygoma. Upper incisors flat ; first upper premolar broadly lanceolate ; crowns of molars rugose ; protoconid and paraconid of first lower molar prominent, subequal, the others rudimental.
	c. Molars $\frac{2}{3}$ <i>Artibeus</i> .
	c'. Molars $\frac{2}{2}$ <i>Dermanura</i> .
	b'. Palatal bones extend to point answering to the anterior third of the zygoma. Upper incisors conical, contiguous ; first premolar narrow lanceolate ; crowns of molars smooth ; all cusps of first lower molar subequal, anterior commissure cuspidate ; molars $\frac{3}{3}$ <i>Sturnira</i> .

II. First lower molar subquadrate without paraconid.

Group Vampyropini.....	d. Hard palate oblong, palatal bones produced. Upper incisors conical.
	e. Angle of lower jaw quadrate, not deflected, posterior border defined. Nasal bones absent in adult ; palate bones produced nearly to the line of glenoid cavity. First upper premolar acicular ; first lower molar with protoconid and mesaconid subequal. Molars $\frac{2}{2}$ <i>Chiroderma</i> .
	e'. Angle of lower jaw acuminate, not deflected. Protoconid of first lower molar aciculate, enormous.
	f. Hypoconid first lower molar rudimental ; molars $\frac{2}{3}$... <i>Vampyrops</i> .
	f'. Hypoconid first lower molar none ; molars $\frac{2}{2}$ <i>Ectophylla</i> .
	d'. Hard palate round, palatal bones scarcely, if at all,* produced.
Group Stenodermini.....	e''. Angle of lower jaw rounded, deflected, posterior border ascending ramus not defined.
	g. Frontal bone in orbit greatly inflated ; palatal bones extend to a point answering to the anterior root of the zygoma ; pterygoids produced, inflated and nearly touching the panicle bones ; upper incisors conical ; protoconid of first lower molar scarcely larger than other cusps ; hypoconid of the same tooth marginal, rudimental molars $\frac{2}{2}$... <i>Pygoderma</i> .
	g'. Frontal bone in orbit not inflated ; palate bone produced to anterior third of zygoma ; upper incisors conical ; protoconid first lower molar enormous ; hypoconid of same tooth marginal ; molars $\frac{2}{3}$ <i>Ame'trida</i> .
	g''. Frontal bone in orbit scarcely inflated ; hard palate with posterior margin excised ; pterygoids not produced. Upper incisors flat ; protoconid of first lower molar enormous.
	h. Palate excised to first molar ; hypoconid of first lower molar inside contour. Molars $\frac{2}{3}$ <i>Stenoderma</i> .
	h'. Palate excised to middle of first molar ; hypoconid of first lower molar marginal. Molars $\frac{2}{2}$... <i>Trichocorys</i> .

* Mr. O. Thomas (*Ann. and Mag. Nat. Hist.*, 1889, p. 70) first employed this character to separate this group from the foregoing.

Measurements of Ectophylla alba (in millimeters).

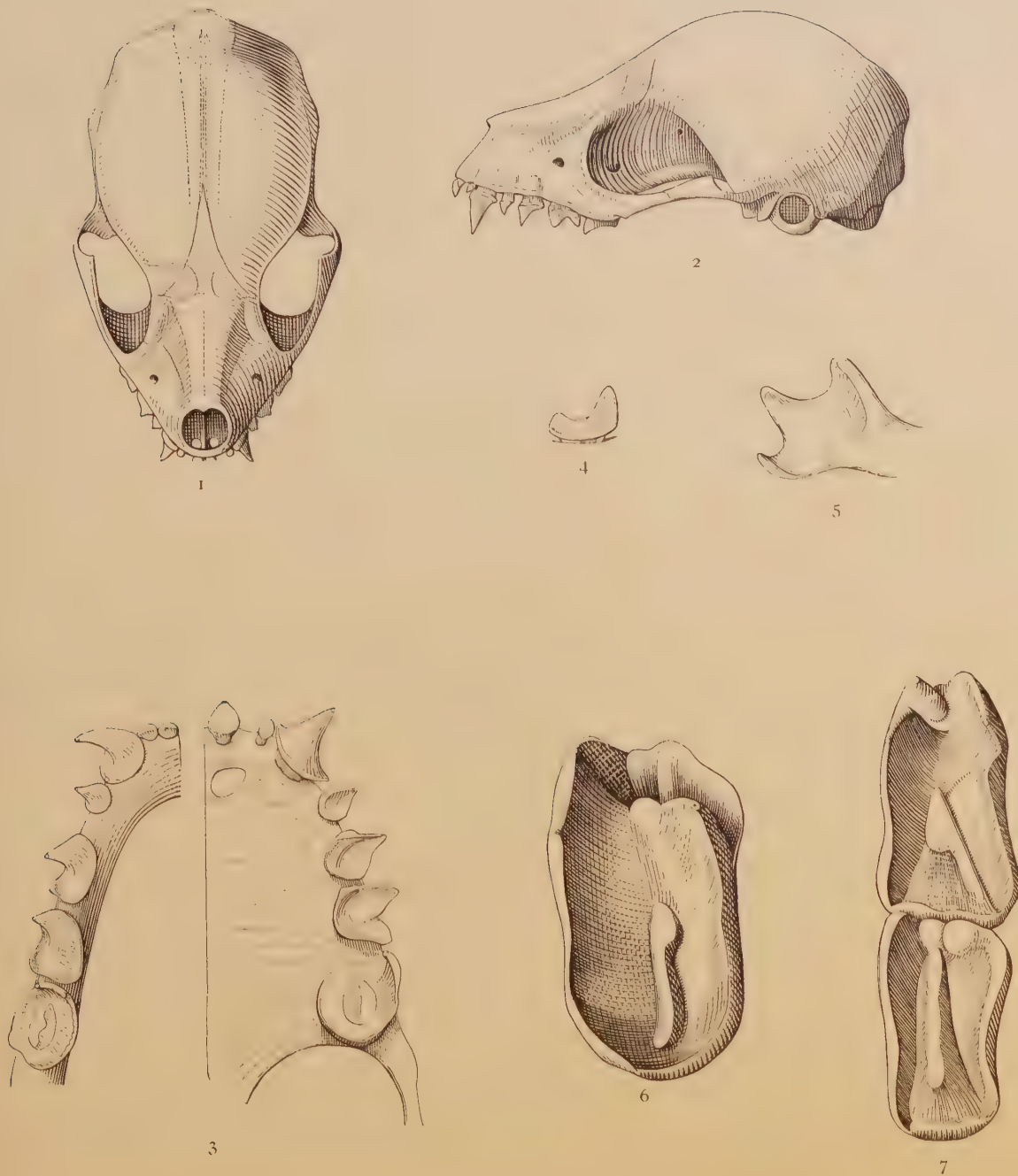
	Type, No. 15950 U. S. N. M.	Mr. O. Thomas' Specimen.
Head and body (from crown of head to base of tail).....	36	36
Length of arm.....	17	
Length of forearm.....	25	26
First digit :		
Length of first metacarpal bone.....	3	3
Length of first phalanx.....	3	3
Second digit :		
Length of second metacarpal bone.....	21	20
Length of first phalanx.....		3
Third digit :		
Length of third metacarpal bone.....	25	25
Length of first phalanx.....	9	8
Length of second phalanx.....	12	13
Length of third phalanx.....	6	6
Fourth digit :		
Length of fourth metacarpal bone.....	25	25
Length of first phalanx.....	7½	8
Length of second phalanx.....	8	7
Fifth digit :		
Length of fifth metacarpal bone.....	25	?
Length of first phalanx.....	6	6
Length of second phalanx.....	7	7
Length of head.....	14	14
Height of ear.....	10	10
Height of tragus.....	5½	?
Length of thigh.....	8½	?
Length of tibia.....	10	10
Length of foot.....	8	8
Length of interfemoral membrane.....	4	4

In concluding the account of this interesting specimen, I will call attention to the molar teeth of *Cephalotes*, a member of the remote group of the Pteropodidæ. The two genera, however, resemble one another in being frugivorous, in retaining few or no tubercles to the molars and, probably on this account, in exhibiting elongated crests in the centre of deeply excavate crowns. A tenable hypothesis for the origin of this central cusp may be expressed as follows. The grinding away of the crowns has gone on to a degree that brings the enamel cap down near to the division in the alveolus, between the sockets for the roots of the teeth, so that this ridge acts as a point of resistance to further wear and leads to a reassertion of the principle of cuspidation at this point.

One of the most marked characteristics of the teeth of fruit-eating bats is the disposition for the loss of cusps in the molar teeth. This takes place without intermediate grades so far as is known. In two of the three subdivisions of the Phyllostomidæ it occurs as exceptions to the rule—*Hemiderma* in the Vampyri and *Phyllonycteris* in the Glossophaginæ, but is the rule rather than the exception in the Stenoderminæ. In the Pteropodidæ the tendency to the loss of cuspidation is the rule, the genus *Pteralopex* being the only exception. Such abrupt variation within the limits of small groups indicates that the tendency to external specialization has weakened the type and exposes it under the influence of environment, ordinarily acknowledged as active in modifying forms, to gross modification always on the side of deterioration.

EXPLANATION OF PLATE XVI.

- Fig. 1. *Ectophylla alba*—norma verticalis.
Fig. 2. *Ectophylla alba*—norma lateralis.
Fig. 3. *Ectophylla alba*—upper and lower teeth.
Fig. 4. *Ectophylla alba*—lower molar (profile).
Fig. 5. *Ectophylla alba*—ramus of lower jaw.
Fig. 6. *Cephalotes peroni*—first right upper molar.
Fig. 7. *Cephalotes peroni*—first and second right lower molars.



ECTOPHYLLA ALBA-CEPHALOTES PERONI.

ARTICLE VII.

(Plates XVII and XVIII.)

THE OSTEOLOGY OF ELOTHERIUM.

BY W. B. SCOTT.

(INVESTIGATION MADE UNDER A GRANT FROM THE ELIZABETH THOMPSON FUND OF THE A. A. A. S.)

Read before the American Philosophical Society, February 4, 1898.

Elotherium is one of the many genera of fossil mammals concerning which the growth of our knowledge has been exceedingly slow, and only of late has it become practicable to give a complete account of its bony structure. The genus was named in 1847 by Pomel ('47 *a, b*) and shortly afterward renamed *Entelodon* by Aymard ('48) from a better specimen, but for several years only the dentition was known and that imperfectly. In 1850, Leidy ('50, p. 90) described the first American species, but, not suspecting its generic identity with the European forms, he at first referred it to a new genus, *Archæotherium*. Leidy's material enabled him to give a fairly complete account of the skull. Kowalevsky, in 1876, described an imperfect skull found in France and he further showed that the feet were didactyl, a very unexpected fact in view of the pig-like character of the dentition. In this country Profs. Marsh and Cope have added materially to our knowledge of this remarkable animal (Marsh, '73, '93, '94; Cope, '79) and the former has published a restoration of one of the species. In spite, however, of this list of workers who have, from time to time, occupied themselves with the study of *Elotherium*, much still remains to be learned regarding its structure, and its phylogenetic relationships are even more obscure.

In the summer of 1894, Mr. H. F. Wells discovered in the White River Bad Lands of South Dakota certain bones, which, with the expenditure of infinite pains and skill, were excavated from the rock by Mr. J. B. Hatcher, and which proved to be a most remarkably complete skeleton of *Elotherium*. This beautiful specimen (Princeton Museum, No. 10885,) formed the subject of a preliminary communication which I made to the third International Zoölogical Congress, at Leyden (Scott, '96), and will be more fully described in the following pages. Except for a single thoracic vertebra (and perhaps a

few caudals) and part of the hyoid apparatus, the skeleton is complete; it is represented in Pl. XVII, which will enable the reader to judge of its unusual state of preservation. Additional material, belonging to several species, will also be made use of for purposes of comparison, but the description will deal almost exclusively with the White River forms.

The Artiodactyla may almost be designated as the despair of the morphologist. So manifold are the forms which this puzzling group has assumed, and so variously are the characteristics of its minor groups combined, that the confusion seems hopeless. The only way in which this tangled skein can be unraveled and its many threads separated and made straight, is by the slow but sure method of tracing the phylogenetic development of each family step by step from its incipient stages. Many years must pass before sufficient palæontological material has been gathered to make this possible, but already some progress has been made in the work. Each successive form in a series, as soon as it is recovered, should be fully described and illustrated for the benefit of other workers, a necessity which must excuse the minuteness of detail into which the following description enters. For the sake of convenience the entire bony structure of the animal will be described, including those parts which are already well known, in order that the reader may be spared the trouble of searching through many scattered papers, written in several languages.

I. THE DENTITION.

The teeth of *Elotherium* are already familiarly known and require but a brief account here. The dental formula is $I \frac{3}{3}, C \frac{1}{1}, P \frac{4}{4}, M \frac{3}{3}$.

A. *Upper Jaw*.—The incisors, three in number, increase regularly in size from the first to the third, the latter being much the largest of the series; it has a conical or somewhat trihedral crown and resembles a canine in shape and appearance. In some individuals the crown of this tooth is worn in a peculiar manner, a deep groove or notch being formed on its posterior side, in a place where it cannot have been made by the attrition of any of the lower teeth. The other incisors have spatulate crowns, with blunted tips, the attrition of use wearing down the apices as well as the posterior faces of these teeth. This description applies more particularly to the larger White River species, such as *E. ingens* and *E. imperator*; in *E. mortoni* the upper incisors are of more nearly equal size and more conical shape. In all, the median incisors are separated from each other by a considerable notch, and the whole series is much more extended antero-posteriorly than transversely, the external incisor standing behind the second one. $I \frac{3}{3}$ is separated by a short diastema from the canine and at this point the premaxillary border is quite deeply notched to receive the lower canine.

The canine is a very large and powerful tusk, with a swollen, gibbous fang; the

crown is long, massive, recurved, and bluntly pointed; it is oval in section, and has a prominent posterior ridge.

The premolars are very simple in construction. The first three are well spaced apart and have compressed, but thick, conical crowns, without accessory cusps of any kind, and each is implanted by two fangs. In size, they increase posteriorly and p^3 has a decidedly higher crown than any other premolar. P^4 is smaller than p^3 in every dimension except the transverse, this diameter being increased by the addition of a large internal cusp (the deuterococone) and the crown is carried upon three fangs. In the smaller species of the genus, such as *E. mortoni*, p^3 and p^4 are placed close together, while in the larger forms these teeth are separated by a short space, and the diastemata between the other premolars and between p^1 and the canine are relatively somewhat greater, the enlargement of these teeth hardly keeping pace with the elongation of the muzzle. In the European species, *E. magnum*, the arrangement of the premolars is somewhat different, p^2 , p^3 and p^4 forming a continuous series, while p^1 and p^2 are quite widely separated.

The molars are relatively quite small; m^2 is the largest and m^3 the smallest of the series. The crowns are low and bunodont, bearing six tubercles arranged in two transverse rows. The hypocone, though functionally important, is decidedly smaller than the protocone, and structurally is still a part of the cingulum. Schlosser is, however, mistaken in supposing that there is any important difference between the American and the European species of *Elotherium* with regard to the position of the protocone. In m^3 , which has a more oval crown than the other molars, the sextitubercular pattern is obscured by the development of numerous small tubercles upon the hinder half of the tooth. The cingulum of the molars is quite strongly marked, especially upon the anterior and posterior faces.

B. Lower Jaw.—The incisors resemble those of the upper jaw, except that they are of more nearly equal size and somewhat more spatulate shape; i^3 is little enlarged and is much smaller than the corresponding tooth in the upper jaw.

The canine is a very large, recurved tusk, like the upper one in size and shape; it bites between the upper canine and enlarged external incisor, the three teeth together making up a very formidable lacerating apparatus. An interesting hint as to the habits of this animal is given by a peculiar mode of wear of the lower canine which occurs in some well-preserved specimens. In these we find a deep groove on the posterior face of the tooth, beneath the enamel cap and close to the level of the gum. No other tooth can reach this point to cause such a mode of attrition, and the groove is doubtless due to the habit of digging up roots with the lower tusks; the pull of the roots, especially when covered with sand or other gritty material, would naturally wear such a groove.* The

* This ingenious and highly probable explanation of a somewhat puzzling fact was suggested to me by my colleague, Prof. C. F. Brackett.

same explanation applies to the curious notches sometimes worn in the external upper incisor. The numerous specimens examined do not indicate that there was any difference between the males and the females in the size of the canines, the tusks being invariably large and powerful. If, as here suggested, the canines served other purposes than those of weapons, the lack of any such sexual difference would be intelligible enough.

The premolars are very simple and quite like those of the upper series in shape; their crowns are massive, compressed cones, without additional cusps. The cingulum is usually prominent, but varies in the different species. $P_{\frac{3}{4}}$ is much the highest of the series, especially in *E. imperator*, where it rises to the full height of the canine, and gives a very characteristic appearance to the lower dentition. $P_{\frac{4}{4}}$ has its posterior face flattened, forming an incipient fossa with a number of small tubercles in it. $P_{\frac{3}{4}}$ and $\frac{4}{4}$ stand quite close together, and $p_{\frac{1}{4}}$ is separated by a short space from the canine, while $p_{\frac{2}{4}}$ is isolated by considerable diastemata both in front of and behind it.

The lower molars are small in proportion to the size of the jaw and to the space occupied by the premolar series. In size they increase posteriorly, and they have a simple, quadritubercular pattern, the crowns surrounded by a strong cingulum. There is much variation in the development of the fifth or posterior unpaired cusp (hypoconulid); it is frequently absent and represented only by a strong cingulum, though sometimes it is present as a distinct cusp on $m_{\frac{1}{4}}$ or $m_{\frac{2}{4}}$. It is less commonly found on $m_{\frac{3}{4}}$ and only in the very large *E. leidyanum* is it well developed.

The Milk Dentition.—The temporary canines and incisors differ from the permanent ones only in size. It is uncertain whether the first premolar, in either jaw, has a predecessor in the deciduous series, none of the specimens distinctly showing such a predecessor. In one individual, however, the tip of p^1 is just visible in the centre of a large alveolus, from which a milk-tooth has apparently been shed. If this change does actually occur, it must take place at an early stage, and, on the whole, it seems probable that, at least in the upper jaw, the number of deciduous premolars is four. Dp^2 has a compressed, elongate, conical crown, without accessory cusps of any kind; it is carried on two widely separated fangs, and is isolated by diastemata both in front of and behind it. Dp^3 consists of three principal cusps. The antero-external cusp (protocone) is an acutely pointed pyramid, while the postero-external cusp (tritococone) is lower and smaller. The internal cusp (tetartocone) is posterior in position and placed on the same transverse line as the tritococone, while between the two is a small conule. The cingulum is distinct on the front and hind faces, obscure on the outer and absent from the inner face of the crown. Dp^4 is molariform, but differs somewhat from the molar pattern in the fact that the postero-internal cusp is even more distinctly an elevation of the cingulum and that the posterior conule is double.

The lower milk-premolars are even simpler than the upper; $dp \frac{2}{3}$ and $\frac{3}{3}$ are compressed and conical, without accessory cusps, but with serrate edges and sharply-pointed summit. Each of these teeth is supported upon two fangs. $Dp \frac{4}{4}$ is of the usual artiodactyl type, consisting of three transverse pairs of cusps, of which the median pair is the largest, and the anterior pair the smallest. A small talon is formed by the elevation of the cingulum in the median line, behind the posterior pair of cusps.

This account of the milk dentition applies only to *E. mortoni*; I have not seen these teeth in the larger species.

Measurements.

	No. 11156	No. 10885	No. 11009	No. 11440
Upper dentition, length I 1 to M 3.....			0.270	
“ molar series, length.....	.118	.104	.064	.065
“ premolar series, length.....	.238*	.175	.124	.113
“ canine, ant.-post. diameter....	.048*	.046	.032	
“ “ transverse diameter.....	.0385*	.042	.022	
“ P 1, length.....	.030*	.024	.019	
“ P 2, “.....	.038*	.038	.025	.023
“ P 3, “.....	.041*		.028	.028
“ P 4, “.....	.035*	.031	.0195	.018
“ M 1, length.....	.035	.033		.020
“ “ width.....		.036		.019
“ M 2, length.....	.042	.035	.025	.023
“ “ width.....		.039	.0235	.024
“ M 3, length.....	.037	.034	.021	.021
“ “ width.....		.033	.022	.0215
Lower dentition, length I 1 to M 3.....	.432*			.261
“ molar series, length.....	.121*	.108		.070
“ premolar series, length.....	.211*	.192		.126
“ P 1, length.....	.028*	.026		.017
“ “ height of crown.....	.026*			.019
“ P 2, length.....	.031*	.033		.020
“ “ height.....	.038*			.023
“ P 3, length.....	.046*	.043		.027
“ “ height.....	.061*			.031
“ P 4, length.....	.046*	.037		.025
“ “ height.....	.044*			.020
“ M 1, length.....	.037*	.031		.0215
“ “ width.....	.029*	.027		.013
“ M 2, length.....	.0395*	.035		.0225
“ “ width.....	.036*	.030		.016
“ M 3, length.....	.043*	.039		.0245
“ “ width.....	.037*	.028		.016

* No. 11161.

II. THE SKULL.

The skull of *Elotherium* is one of the most remarkable features of this very curious animal. It is characterized by great length and slenderness, with the supraoccipital and nasal bones lying in the same horizontal plane. The muzzle is exceedingly long and narrow, and tapers somewhat anteriorly, though expanded by the sockets of the great tusks; the orbit has been shifted far back, its anterior border being, in some species, over m^2 , and in others above m^3 . The cranium is short and of absurdly small capacity, which, with the great temporal openings, gives an almost reptilian appearance to the skull when viewed from above or below. The sagittal crest is very high and thin, and the zygomatic arches, though rather short, are enormously developed. One of the most peculiar features of the skull is the great, compressed plate which is given off from the ventral surface of the jugal and descends below the level of the lower jaw, and this grotesque appearance is further increased by two pairs of knob-like processes on the ventral borders of the mandible. The occiput (Pl. XVIII, Figs. 1, 2) is high and very broad at the base, but narrowing rapidly to the summit; above the foramen magnum it forms a broad, flat projection of almost uniform breadth, with a very deep fossa on each side of it.

The *basioccipital* is stout and rather short, keeled in the median ventral line and slightly contracted to receive the auditory bullæ; at its junction with the basisphenoid it forms a pair of small, roughened tubercles. The *exoccipitals* are very large bones, especially in the transverse direction along the base of the occiput, dorsally they narrow fast. Above the foramen magnum they form the very broad, prominent and nearly square projection which has already been mentioned; this is thick and is filled with cancellous bone, the fossa for the vermis of the cerebellum making but a slight depression upon its internal face. On each side of the projection is a large and deep triangular fossa, which, however, is not confined to the exoccipital, the periotic and squamosal both being concerned in its formation. The inferior part of the exoccipital extends widely outward, reaching to the line of the glenoid cavity, and ending in the large, prominent and massive, but not elongate paroccipital process. In this region the exoccipital is brought very close to the zygoma, but, ventrally at least, does not quite touch it, a narrow band of the tympanic intervening between them. The foramen magnum is strikingly small and of a transversely oval shape. The occipital condyles are relatively rather small, especially in the vertical dimension, laterally they are well extended, and they are widely separated both above and below. In the very large *E. imperator* the external angles of the condyles are abruptly truncated in a curious way, and bear flat articular surfaces, though in some individuals this truncation is found only on one side; while in the smaller species the condyles are of the usual form. The *supraoccipital* is a large bone, widest at the base (*i. e.*, the suture with the exoccipitals) and narrowing dorsally. Superiorly it is drawn out into two posterior wing-

like processes, such as are found in *Oreodon* and other White River ungulates. Between these wings the hinder face of the bone is concave and at the bottom of this concavity are two small, but profound pits. The supraoccipital is continued over upon the roof of the cranium and forms a part of the sagittal crest.

A considerable part of the *periotic* is exposed on the surface of the skull, at the bottom of the lateral occipital fossa, where it is enclosed between the exoccipital and the squamosal; it does not give rise to any distinct mastoid process.

The occiput of the European species, *E. magnum*, as figured by Kowalevsky ('76, Taf. XVII, Fig. 5), is different in many details from that which characterizes the American species. It has more of an hour-glass shape, not so wide at the base, more contracted in the middle and more expanded at the top, but with much less conspicuous wing-like processes, and it has no such projection above the foramen magnum, nor such deep lateral fossæ. The condyles are larger and of an entirely different shape, having their principal diameter vertical, instead of transverse. The paroccipital processes are longer, more compressed and not so widely extended laterally. The foramen magnum is large and of more nearly circular outline.

The *basisphenoid* is narrower than the basioccipital and is not keeled on the ventral surface, but is otherwise like that bone. So much of its course is concealed by the union of the palatines and pterygoids along the median line that its length cannot be determined, while the presphenoid is nowhere exposed to view.

The *tympanic* is very extensively developed (Pl. XVIII, Fig. 1). Part of it is inflated into an oval, somewhat flattened and rather small auditory bulla, which differs from that of *Hippopotamus* and of all existing suillines in being hollow and not filled up with spongy tissue. On the outer side of the bulla the tympanic is extended as a narrow strip, which broadens considerably between the squamosal and the exoccipital, with both of which it articulates suturally, as well as with the alisphenoid in front. The bulla itself terminates anteriorly in a blunt spine.

The *alisphenoid* is small and forms very little of the side of the cranium. It is most elongate antero-posteriorly along the ventral line, but has hardly any distinctly developed pterygoid process. At the line of the sphenoidal fissure, which notches but does not perforate the bone, the alisphenoid is narrowed, to expand again at its suture with the parietal and frontal. The *orbitosphenoid* is relatively rather large, but is low in the vertical dimension, and does not extend upward into the orbit proper. Two sharp ridges on the external face of the bone enclose a V-shaped groove, in which lie the optic foramen and foramen lacerum anterius.

The *parietals* are very large proportionately to the size of the cranium, but quite small as compared with the entire length of the skull; they roof in most of the cerebral

chamber, but toward the ventral side they rapidly contract, forming narrow strips between the squamosal and frontal. Throughout their length the parietals unite to form the very high, thin and plate-like sagittal crest, which is one of the most characteristic features of the skull. In the European species, *E. magnum*, this crest has a remarkably straight and horizontal course, but in the known American species it is gently arched from before backward. Large sinuses are developed in the parietals, so that the cerebral chamber is even smaller than it appears to be, when viewed from the outer side. These sinuses extend over the entire roof of the cerebral fossa, even invading the supraoccipital; they appear to be traversed by numerous small trabeculæ, the ends of which are seen, in the sagittal section, embedded in the matrix which fills the sinuses.

The *frontals* are much larger than the parietals. In the postorbital region they are very narrow, in conformity with the very small size of the brain, but at the orbits they expand widely to form the broad, lozenge-shaped forehead, which is convex from side to side, though slightly depressed, or "dished" in the middle; the supraciliary ridges are very inconspicuous. Anteriorly the frontals diverge to receive the nasals between them, sending forward long, pointed nasal processes, which, owing to the great elongation of the muzzle, are widely separated from the premaxillaries. The orbit is large and projects prominently outward; it is completely encircled by bone, the long and massive postorbital process of the frontal uniting suturally with the shorter process of the jugal. The orbits do not rise above the level of the forehead, as they do in *Hippopotamus*, and present more anteriorly, less directly outward, than in that animal. Mention has already been made of a groove on the orbitosphenoid, which terminates below and behind in the foramen lacerum anterius; this groove is continued upward and forward upon the frontal, steadily widening as it advances. The postero-superior ridge bounding the groove is the more prominent; it extends almost to the postorbital process, from which it is separated by a distinct notch, while the antero-inferior ridge dies away within the orbit. In most of the American species the forehead rises very gradually and gently behind to the sagittal crest, but in *E. ingens* the rise is much more sudden and steep. The frontal sinuses are large, giving the convex shape to the forehead which has been described; these sinuses appear to communicate with those formed in the parietals.

Except posteriorly, the *squamosal* forms but little of the side-wall of the cranium, its suture with the parietal curving abruptly downward and forward; its compressed and prominent hinder margin forms nearly the whole of the lambdoidal crest, though a continuation of it extends upward upon the supraoccipital, ending in the wing-like processes of that bone. The zygomatic process is enormously developed; it extends widely outward from the side of the skull as a massive, vertical plate, which is shaped much as in *Hippopotamus*, and is not continued forward as a broad, horizontal shelf, such as is found

in *Sus*. The superior border curves upward into a great, hook-shaped process, which resembles that seen in *Merycochoærus*, and gives a highly characteristic appearance to this region of the skull. That portion of the zygomatic process which is directed anteriorly is short and, though massive, is much less so than that which extends out laterally; in front it is received into a notch of the jugal. The glenoid cavity is large, transversely directed and quite deeply concave, though the postglenoid process is not strongly developed and is hardly more conspicuous than the preglenoid ridge. This disposition is unusual among the ungulates, but it occurs also in the Eocene genus *Achænodon* and in the modern *Dicotyles*. The glenoid cavities of the two sides are very widely separated, their *inner* margins lying external to the line of the paroccipital processes. The posttympanic process of the squamosal is small, and is closely applied to the paroccipital process. The shape of the zygomatic arches, together with the extreme narrowness of the cranium proper, causes the temporal openings to be very large and to appear widely open when the skull is viewed from above. These openings are, however, less extended transversely and more antero-posteriorly than in *Hippopotamus*, while in *Sus* they are hardly visible from above.

The *jugal* is a very remarkable bone and constitutes one of the most extraordinary features of the *Elotherium* skull. Posteriorly it is notched to receive the zygoma, and sends out a process along the ventral face of that bone, extending to the preglenoid ridge. The jugal forms the inferior half of the nearly circular orbit, and for this purpose its dorsal border is made deeply concave, giving off a stout postorbital process to meet that of the frontal, while anteriorly it is moderately expanded upon the face in front of the orbit, where it is wedged in between the lachrymal and the maxillary. The most peculiar feature of the jugal, however, is the immensely developed vertical plate, which descends from beneath the orbit downward and outward to below the level of the ventral border of the mandible, recalling the similar, but much less massive processes found in certain edentates, *e. g.*, *Megatherium*. These plates are laterally compressed, but quite thick, and when the skull is viewed from the front, they are seen to diverge quite strongly downward; their shape varies in the different species. In the very large forms from the Protoceras beds, such as *E. imperator*, the process retains its plate-like form throughout, its free end being only moderately thickened. This appears to be true also of *E. mortoni*, though my material is not sufficient to allow me to make this statement positively, but in the large species from the Titanotherium and Oreodon beds (*E. ingens*) it forms a club-like thickening at the tip, which in *E. ingens* is coarsely crenulate on the posterior border (see Pl. XVII). These processes are, so far as is yet known, quite unique among the hoofed mammals, and it is difficult to form even a conjecture as to what their functional significance may have been. Some misunderstanding has arisen as to the spe-

cies in which these jugal plates are found. Nothing is known concerning their presence or absence in the European representatives of the genus. Leidy's material gave him no reason to suspect their occurrence in the species described by him, and he consequently restored the zygomatic arches without them ('69, Pl. XVI). Marsh first discovered the processes in a skull of the species named by him *E. crassum*, and it has sometimes been assumed that they were more particularly characteristic of that form. As a matter of fact, they have been observed in all of the American species of which well-preserved skulls are known, viz., *E. mortoni*, *E. ingens*, and *E. imperator*, and, in all probability, all the American forms, at least, possessed them.

The *lachrymal* is a rather large bone and forms nearly half of the anterior boundary of the orbit. On the face it is expanded into quite a large plate, which articulates below with the jugal, in front with the maxillary, and above with the frontal, the long anterior process of which prevents any contact between the lachrymal and nasal. In *Hippopotamus* the very short, broad frontal has no anterior process, and so the nasal and lachrymal are connected, as they are also in *Sus*. Within the orbit the lachrymal is but little extended; the foramen is single, very small, and placed inside the orbital margin. The lachrymal spine is very low.

The *nasals* are narrow, slender and very much elongated. Their greatest width is at the anterior end of the nasal processes of the frontal, and here is also their greatest transverse convexity; from this point they narrow and flatten, both in front and behind. Anteriorly they contract very gradually and terminate in sharp points, with their free ends quite deeply notched. In *E. ingens* the nasals appear to be relatively shorter than in the other species. In *Hippopotamus* these bones have much the same shape as in *Elotherium*, but they narrow more abruptly behind the point of greatest width, and their free ends are not notched. In *Sus* the nasals are truncated posteriorly and in front their free tips project far beyond the borders of the premaxillaries.

The *premaxillaries* are very large and heavy bones, the horizontal or alveolar portion especially so. Posteriorly, this portion is constricted, forming a groove for the reception of the lower canine, expanding again in front to carry the large incisors. The palatine processes are not much developed, the very large incisive foramina leaving but little space for them; the spines are long and slender, extending behind the canine alveolus. The ascending ramus of the premaxillary is low and rises gradually behind, and though broad at first, it rapidly becomes very slender, terminating behind in a fine point. Though these bones in *Elotherium* have a very different appearance from the immensely enlarged premaxillaries of *Hippopotamus*, yet both may have been formed by divergent modifications of a common plan.

The *maxillary* is greatly extended antero-posteriorly, in correspondence with the

elongation of the whole muzzle; its facial portion is low, gradually diminishing in height forward, where its suture with the premaxillary forms a very gentle, sweeping curve. The longest suture of the maxillary is that with the nasal, the connection with the frontal being very short, owing to the extension of the lachrymal. Posteriorly, this bone projects but little beneath the orbit, which has an imperfectly developed floor, and the projection which it sends out to the jugal is much less massive than in *Hippopotamus*. The face gradually narrows forward, until it reaches the infraorbital foramen, expanding again in front of the foramen and swelling out into the prominent canine alveolus. The palatine processes of the maxillaries are long and narrow, and as the molar-premolar series of the two sides form almost straight and parallel lines, the bony palate is of nearly uniform width, slightly concave transversely, but almost plane antero-posteriorly. In front, these palatine processes are deeply emarginated by the large incisive foramina, and in the median line are still further notched to receive the long premaxillary spines.

The *palatines* make up but very little of the bony palate, forming only a narrow strip in front of the posterior nares, and narrow bands along the sides. The palatal notches are small and shallow. The *pterygoids* are elongate, but quite low; there are no hamular processes or pterygoid fossæ; the two bones meet suturally along the median dorsal line, completely concealing the presphenoid from view. The posterior nares are long, narrow and low, extending forward to the middle of m²; the opening gradually contracts posteriorly, where it becomes very narrow, while the side-walls slope upward and die away upon the alisphenoids. Anteriorly the nares are divided by the very large *vomer*, which is distinctly visible, and which at its hinder termination expands into a transverse plate, articulating with the palatines. The meeting of the two pterygoids forms a small canal, which appears to overlie the whole length of the posterior nares and to open forward into the nasal chamber on each side of the vomer. This is a very exceptional arrangement, and I am unable to suggest what its functional meaning may be (see Pl. XVIII, Fig. 1, *c*).

The *cranial foramina* are, in some respects, quite peculiar. The condylar foramen is large and conspicuous, being placed well in front of the condyle; it is, however, smaller than in the specimen of *E. magnum* which Kowalevsky has figured. The close approximation of the paroccipital and stylomastoid processes, and the outward extension of the tympanic between them, have given a somewhat unusual position to the postglenoid and stylomastoid foramina; they are crowded close together at the postero-external angle of the auditory bulla, and both of them perforate the enlarged tympanic bone. The foramen lacerum posterius forms a long, narrow and curved slit at the postero-internal angle of the bulla, while the foramen lacerum medium and the opening of the eustachian canal occupy their ordinary position at the front end of the bulla. No distinct carotid canal is visible externally.

Kowalevsky inferred from the study of his specimen that the foramen ovale "nicht als selbständiges Foramen existirte, wie z. B. bei den Ruminanten, sondern mit dem For. lac. med. verschmolzen war, wie bei den heutigen Suiden und bei Hippopotamus" ('76, p. 433). This is probably a mistake; at all events, it is not true of the American species, in which the foramen ovale is a long, conspicuous opening, of oval shape, perforating the alisphenoid. As in the ungulates generally, there is no separate foramen rotundum, that opening being fused with the foramen lacerum anterius. The latter is a large and somewhat irregular opening, which notches the anterior border of the alisphenoid, passing between that bone and the orbitosphenoid. The optic foramen is small and well separated from the foramen lacerum anterius, lying in front of and at a slightly higher level than the sphenoidal fissure; it does not open so far forward as in *E. magnum*, and, in consequence, it does not form such a remarkably elongated canal as in the European species (see Kowalevsky, '76, Taf. XVI, Figs. 1 and 3, *dd*), but, on the other hand, it is far from being a simple perforation of the orbitosphenoid, such as occurs in the recent ungulates. This elongation of the optic canal should probably be correlated with the very small size of the brain, which would seem to have been relatively smaller than in the ancestors of the genus. Though the orbits are far behind their primitive position, the backward shifting of the optic tract would seem to have kept pace with the change in the position of the orbits.

The posterior palatine foramina are large and conspicuous openings, placed at the maxillo-palatine suture, and separating the two bones at these points; the palatine plates of the maxillaries are deeply grooved for some distance in front of the foramina. The incisive foramina are likewise large, invading both the maxillaries and the premaxillaries; indeed, their size prevents the development of any considerable palatine processes on the latter bones. These foramina are in very marked contrast to those of *Hippopotamus*, in which the enormously expanded and massive premaxillaries are perforated by two small and widely separated openings; in *Sus* also the incisive foramina are proportionately much smaller than in *Elotherium*. The infraorbital foramen is large and is separated from the orbit by a considerable interval, opening above the anterior border of p ³. In front of the foramen a deep groove channels the outer face of the maxillary for a short distance. The canal itself is much elongated, in correspondence with the great length of the jaws, and its posterior orifice, within the orbit, is very large. The lachrymal foramen, which is single, is quite small and is placed inside of the orbit.

The supraorbital foramen is subject to some variation in the different species. In *E. ingens*, from the Titanotherium beds, these openings are of good size, are placed quite near to the median line, and have well-marked vascular channels running forward from them. In specimens of *E. mortoni* from the Oreodon beds, and in the very large species

(*E. imperator*) from the Protoceras beds, the openings have become minute; they are shifted laterally and have no anterior grooves leading from them.

The *mandible* is not the least curious part of this remarkable skull. The horizontal ramus is extremely long and nearly straight, with an almost horizontal inferior border. The depth and thickness of the ramus vary considerably; even in skulls of the same length the mandible is decidedly more slender in some specimens than in others. The materials are, however, not yet sufficient to determine whether this difference is of a specific, sexual, or merely individual character. A remarkable knob-like process is given off from the ventral border of the mandible, beneath $p \frac{1}{4}$, which is subject to much variation in shape and elongation, in accordance with the age and size of the animal. In young individuals still retaining the milk-dentition, the process is a mere rugose elevation, and in the adults of the smaller species it is hardly more than a knob, while in the large forms it becomes greatly elongated and club-shaped. No marked difference in this regard is observable between the species from the upper and those from the lower horizons of the White River formation, the process being relatively quite as long and prominent in *E. ingens* from the Titanotherium beds, as in *E. imperator* from the Protoceras beds, but in the huge John Day species it has become particularly long and heavy.

The symphysis is quite long and very thick and massive; the two rami are indistinguishably fused together and laterally expanded, so as to somewhat resemble the symphysis of *Hippopotamus*, though not attaining any such extreme degree of massiveness as in the modern genus. The chin is abruptly truncated and flattened, and rises very steeply from below; on each side, beneath or a little behind the canine alveolus, there arises from the ventral border a second club-shaped process, similar to, but much heavier and more prominent than the posterior process already described. These two pairs of knobs give to the jaw a highly peculiar and characteristic appearance; they form another of the enigmatical features of the *Elotherium* skull, for it is difficult to imagine what part they can have played in the economy of the animal.

The two inferior dental series pursue a nearly parallel course, diverging backward but little, but behind the molars the two rami turn outward and diverge rapidly, so that posteriorly they are very widely separated, in correspondence with the great interval between the glenoid cavities of the two squamosals. The angle of the mandible is prominent and descends below the ventral border of the horizontal ramus, much as in *Hippopotamus*, though not to the same extent. The ascending ramus is not high, but of considerable antero-posterior extent. The masseteric fossa is quite small, but very deeply impressed, and is situated quite high upon the side of the jaw. The condyle is relatively little raised above the level of the molar teeth, and it is sessile, hence inconspicuous, though it is large, transversely expanded, and strongly convex. The coronoid process

is strikingly low and small; it is of triangular shape, erect and not at all recurved, and is separated from the condyle by a very wide sigmoid notch. The mental foramen is small, single, and placed below p $\bar{2}$.

Several of the *hyoid* elements are preserved in connection with the skeleton of *E. ingens* which forms the principal subject of this description. The stylohyal is quite long and slender; its proximal portion is laterally compressed and very thin, but moderately broadened in the fore and aft direction. For the distal two-thirds of its length the bone is thicker and of a compressed oval section, expanding into a club-shaped thickening at the lower end, which is excavated for the connecting cartilage. The ceratohyal is considerably shorter than the stylohyal, but of quite similar shape; its proximal end bears a cup-shaped expansion, beneath which it becomes very thin and much compressed, but broadened antero-posteriorly; the inferior part of the shaft is slender and oval in section, with another cup-shaped expansion at the distal end. The epihyal and basihyal have not been preserved. The thyrohyal is of remarkable length and slenderness, and obviously was not coössified with the basihyal; the bone is of subcylindrical shape, with expansions at the proximal and distal ends.

This hyoid apparatus does not resemble that of any artiodactyl with which I have been able to compare it. The elements of the anterior arch somewhat resemble those of *Hippopotamus*, but are more slender and elongate. In the modern genus, on the other hand, the thyrohyals are very short, and are ankylosed with the basihyal, a totally different arrangement from that which characterizes *Elotherium*.

From the foregoing description and accompanying figures it will be obvious that the skull of *Elotherium* is an extremely peculiar one. Among recent animals that of *Hippopotamus* approximates it most closely, and displays, with many striking differences, several decided and, it may be, significant resemblances. Some of these resemblances, such as the straight cranio-facial axis and the long sagittal crest, are of no particular importance, because they occur so very generally among the primitive ungulates of all groups. Other similarities, again, are not of this nature. The proportions of the cranial and facial regions, the degree of backward shifting of the orbits, the relations of the zygomatic and paroccipital processes, the broadening of the muzzle, and the general plan of skull construction, are all similar in the two genera. On the other hand, each genus has certain peculiarities correlated with its manner of life. Thus, the elevation of the orbits and the backward displacement of the posterior nares in *Hippopotamus* are adaptations to its aquatic habits. Doubtless the extraordinary peculiarities of *Elotherium*, such as the dependent processes of the jugals and the great knobs on the mandible, are of a similar nature, though, in the absence of the soft parts, it is difficult even to conjecture what their use may have been.

Measurements.

	No. 11156.	No. 10885.	No. 11009.	No. 11440.
Skull, extreme length on basal line.....	0.803	?0.618	?0.460	
“ width across zygomatic arches (behind jugal process)...	?500	.443	.297	.264
“ width at p \pm.....	.133	.140	.089	.082
Cranium, length to anterior border of orbit.....	.282	.288	.198	.193
Face, length to anterior border of orbit.....	.518	?378	.270	
Occiput, breadth of base.....	.281	.252	.160	.158
“ height.....	.158		.120	
Bony palate, length in median line.....		?376	.247	
Zygomatic arch, length.....	.279	.271	.146	.146
Descending process of jugal, length.....	.330	.256		.126
Mandible, length.....	.659*	.608		
“ height at coronoid process.....	.253*	.171		.107
“ depth at p \mp.....	.133*	.091		.052

* No. 11161.

III. THE BRAIN.

Attention has been repeatedly called, in the foregoing description of the skull, to the extraordinarily small size of the brain-cavity. Even on viewing the skull externally, this smallness of the cranium proper strikes the observer immediately, and, in connection with the long, slender muzzle, gives the skull something of a reptilian aspect. When the cranium is sawn open in longitudinal section, it becomes apparent that the brain is even smaller than would be inferred from the external view alone, much of the space being, so to speak, wasted in the great frontal and parietal sinuses which overlie the whole cerebral chamber. In a large, full-grown skull this chamber will hardly contain an ordinary human fist.

The *olfactory lobes* are very large and are connected with the cerebrum by short thick olfactory tracts. The lobes are not at all overlapped by the hemispheres, but are entirely exposed for their whole length.

The *cerebral hemispheres* are relatively small, though they are, of course, much larger than the other segments of the brain; so short are they that they do not extend over the olfactory lobes in front, or the cerebellum behind. In shape, they are low and wide, narrowing gradually forward, but with blunt anterior termination. The frontal lobe is very small, for the frontals take but little share in the roof of the cerebral chamber. The parietal lobe, on the other hand, is relatively large and forms the greater part of the hemisphere, for there is, properly speaking, no occipital lobe, the occipital bones not taking any part in the formation of the cerebral fossa. The temporo-sphenoidal lobe is also quite large and prominent, but is short antero-posteriorly. The brain-cast shows that the

hemispheres were convoluted, but the convolutions are so feebly marked that they are hardly worth description. It is obvious, however, that the gyri were fewer and simpler than in any of the modern ungulates.

The *cerebellum* is rather small, though the cerebellar fossa has a vertical diameter not much less than that of the cerebral fossa. Antero-posteriorly the former is quite short and its transverse breadth is not great. This breadth is still further reduced by the relatively very large size of the periotic bones which extend freely into the fossa.

IV. THE VERTEBRAL COLUMN.

The vertebral formula is: C 7, Th ? 13, L 6, S 2, Cd 15 +

The *atlas* (Pl. XVIII, Fig. 3) is very wide transversely, and at the same time it is of considerable antero-posterior extent, a shape which recalls that of *Anoplotherium*, rather than that of the recent ruminants or suillines. The anterior cavities for the occipital condyles are deep and wide, but low and depressed. Dorsally, these cotyles are widely separated by a broad, but not very deep emargination of the neural arch, nor do they approximate each other very closely on the ventral side, a notch of considerable width intervening between them at this point. The neural arch is thick and heavy, but short from before backward and quite narrow transversely; it is also low, not arching strongly toward the dorsal side, and nearly smooth, being free from any but the most obscurely marked ridges. The foramina perforating the arch for the first pair of spinal nerves are unusually large. The neural spine is rudimentary and forms only an inconspicuous tubercle. The neural canal is low and broad, forming a transversely directed ellipse. The inferior arch is considerably more elongated antero-posteriorly than the neural, and has but little transverse curvature, except laterally, where it rises to form the sides of the neural canal. The hypapophysis is represented by a small, backwardly directed tubercle, which arises from the hinder margin of the ventral arch, and occupies the same position as in the pigs, but is much less strongly developed. The articular surfaces for the axis are low and broad, and have a very oblique position, presenting inward toward the median line, almost as much as backward; they have also a slight dorsal presentation. In shape, they are very slightly concave and are surrounded by prominent borders. The facet for the odontoid is wide, and deeply concave in the transverse direction, but quite short antero-posteriorly. This facet is connected at the sides with those for the centrum of the axis, but distinct ridges are formed along the line of junction.

The transverse processes of the atlas extend out widely from the sides of the arch, attaining their greatest transverse breadth along the posterior line; they are also very long in the fore-and-aft direction, reaching far behind the surfaces for the axis. For most of their course the transverse processes have thin borders, but posteriorly the

margin becomes much thicker and more rugose. The vertebrarterial canal, which is notably small, occupies much the same position as in *Sus*, opening posteriorly upon the dorsal side of the hinder border. The anterior extension of the transverse processes has converted into foramina (atlanteo-diapophysial) the notches for the inferior branches of the first pair of spinal nerves. On the ventral face of each process is a large fossa, enclosed between the side of the inferior arch and the greatly thickened posterior border of the process. The resemblance in shape to the atlas of *Anoplotherium*, to which attention has already been called, affects more particularly the form of the transverse processes but they are more extended transversely than in that genus and are not so pointed at the postero-external angles.

The *axis* (Pl. XVIII, Fig. 4) is a short, but very massively constructed bone, which in general shape and appearance resembles that of *Hippopotamus*. The centrum is short, anteriorly very broad and depressed, but thickening posteriorly, and with a nearly circular and slightly concave hinder face. A strong and prominent keel runs along the ventral face of the centrum, enlarging backward, and terminating behind in a trifid hypapophysis. The odontoid process is short, heavy and conical, with no tendency whatever to assume the depressed and flattened shape which occurs in so many White River ungulates. The ventral articular surface of the odontoid seems like something super-added to the process itself, for it is clearly demarcated by a groove running all around it, and projects slightly in front of the body of the process. On the dorsal side of the centrum a broad and well-defined ridge runs backward from the odontoid along the floor of the neural canal. The atlanteal articular surfaces are very broad and low, not rising so as to enclose any part of the neural canal. They are very oblique with reference to the median line of the centrum, with which they form angles of about 45° . These surfaces are slightly convex in both directions, and ventrally they project much below the level of the centrum.

The transverse processes are short, thin and compressed, much less massive and widely extended than in *Hippopotamus*; they are perforated by very large foramina for the vertebral arteries. The pedicels of the neural arch are low and short, but very heavy; they are not pierced for the passage of the second pair of spinal nerves, as they are in *Hippopotamus* and in some of the pigs. The neural canal is decidedly small, especially its anterior opening; behind, it enlarges somewhat, particularly in the dorso-ventral dimension, the posterior opening being high and narrow, while in *Hippopotamus* it is low and broad. The neural spine is a large plate which is very thin in front, but becomes thick and massive behind, ending in a broad rugosity. This spine resembles that of *Hippopotamus*, but is not produced so far backward and does not overhang the third cervical. The postzygapophyses are large, slightly concave, and present obliquely

outward, as well as downward; their bases are separated by a broad and deep groove, which is continued upward upon the posterior side of the neural spine.

The *third cervical vertebra* also bears a considerable resemblance to that of *Hippopotamus*, differing only in some points of detail. The centrum is short, heavy and moderately opisthocœlous, depressed, but increasing posteriorly in vertical thickness. It bears a strong ventral keel, which terminates behind, as in the axis, in a trifid hypapophysis. The pedicels of the neural arch are not, as in the pigs, pierced by foramina for the spinal nerves; they are low and short, but very thick, and the neural canal is strikingly small. The dorsal side of the arch is short, broad and nearly flat. The neural spine is remarkably well-developed (when the anterior position of the vertebra is taken into account), rising as high as that of the axis. It is rather thin and compressed, although its base occupies the whole fore-and-aft length of the arch. From the base, however, it rapidly tapers upward and terminates in a small, rough tubercle. In *Hippopotamus* the third cervical has an even better developed neural spine, not higher, but broader and less tapering than in *Elotherium*. The prezygapophyses are large, oblique and somewhat convex; they are placed very low, so that their inferior margins are separated from the centrum only by narrow notches. The posterior zygapophyses are much larger and more prominent than the anterior pair; they are also less oblique in position and are raised higher above the centrum, corresponding to the posterior elevation of the neural arch. The transverse process is a compressed plate, which has no great vertical height, but is well extended from before backward, exceeding the centrum in length; the posterior portion of the process is thickened and recurved, ending in a rugose hook. The absence of any distinctly marked diapophysial element distinguishes this vertebra from the corresponding one of *Hippopotamus* and *Sus*, and in the latter genus the inferior lamella is more slender and rod-like, while the spinal nerves make their exit through foramina in the pedicels of the neural arch.

The *fourth cervical vertebra* is different, in many respects, from the third. The centrum is somewhat shorter and is less distinctly carinate on the ventral side, but is more decidedly opisthocœlous. The neural arch is remarkably short in the antero-posterior dimension, so that the articular faces of the postzygapophyses actually extend forward beneath those of the anterior pair, which gives to the pedicel of the neural arch, when seen from the side, a curiously notched appearance. The neural spine is higher, but more slender and recurved than that of the third cervical. The transverse process is altogether different in shape from that of the latter. It has, in the first place, a very prominent diapophysial element, which projects outward as a heavy, depressed bar, thickened, rugose, and slightly upcurved at the distal end. In the second place, the inferior lamella is much higher vertically, but decidedly shorter from before backward.

In *Hippopotamus* and in *Sus* this vertebra is very similar to that of *Elotherium*, but the neural spine is notably heavier.

The *fifth cervical vertebra* has an even shorter neural arch than the fourth and a much higher neural spine. The spine tapers rapidly from the base upward and becomes very slender, but it is nearly straight and only slightly recurved. The neural canal is somewhat larger than in the fourth vertebra, but, as in all the cervicals, it is strikingly small as compared with the size of the vertebra as a whole. The diapophysis is strong and prominent, but more slender than on the preceding vertebra, while the inferior lamella, though relatively short from before backward, has attained great vertical height and is strongly everted. In *Elotherium* the fifth vertebra is of the same type as the sixth, whereas in *Hippopotamus* it more nearly resembles the fourth.

The *sixth cervical* is very like the fifth, but displays certain obvious differences. Thus, the neural arch is even shorter antero-posteriorly, and the neural spine is higher, heavier and much more strongly recurved. The postzygapophyses are decidedly smaller and are very characteristic in their markedly oblique position, for they rise steeply backward in a way that occurs in none of the other vertebræ. The diapophysis is shorter but heavier than that of the fifth, while the inferior lamella is of similar shape, but larger, higher and with the free margin more thickened. In *Hippopotamus* this vertebra has much the same construction as in *Elotherium*, but the spine is shorter and more massive and the inferior lamella is much larger. In *Sus* the sixth cervical bears considerable resemblance to that of the White River genus.

The *seventh cervical* is characterized by the height and thickness of the spine, which in these respects much exceeds that of the sixth. This spine tapers superiorly, but expands again at the tip into a rough tubercle. The posterior zygapophyses stand at a higher level than the anterior pair and are unusually concave. The peculiarities seen in the postzygapophyses of the sixth and seventh vertebræ are to provide for the curvature of the neck, which changes its direction at this point. From the occiput to the sixth cervical the neck is nearly straight and inclines downward and backward, while the seventh vertebra begins the rise which culminates in the anterior thoracic region. This change in direction requires greater freedom of motion, which is supplied by the modification of the zygapophyses upon the vertebræ mentioned. The transverse process is, as usual, not perforated by the vertebrarterial canal; it is rather short, but heavy and much expanded at the distal end. On the posterior face of the centrum are large facets for the heads of the first pair of ribs. In *Hippopotamus* the neural spine of the seventh cervical is relatively much longer and heavier than in *Elotherium* or in *Sus*.

As a whole, the neck of *Elotherium* is short and massive, with very strongly developed processes for muscular and ligamentous attachments, as are indeed necessitated

by the immense weight and length of the head. Among recent artiodactyls *Hippopotamus* has cervical vertebræ most like those of *Elotherium*, though there are many differences in the details of construction. The most apparent of these differences lies in the greater and more uniform height and thickness of the neural spines in the modern genus. Doubtless the even more exaggerated massiveness of the skull in the latter is the occasion of this increased development of the cervical spines. In *Sus* the perforation of the neural arches for the passage of the spinal nerves constitutes an important difference from *Elotherium*.

The *thoracic vertebræ* would appear to have numbered thirteen, though this point cannot, as yet, be determined with entire certainty, and while the thoraco-lumbar vertebræ were, in all probability, nineteen in number, as is well-nigh universal among the artiodactyls, yet there were doubtless variations in the number of ribs, as is very frequently the case among existing animals.

The first thoracic has a rather small centrum, with decidedly convex anterior and nearly flat posterior face; the facets for the rib-heads are very large and deeply concave. The transverse process is rather short, but very large, heavy and rugose, and bears an unusually large, concave facet for the tubercle of the first rib. The prezygapophyses are of the cervical type, but present more obliquely inward than in the vertebræ of the neck, while the postzygapophyses are, as in the other thoracics, placed upon the ventral side of the neural arch. The neural canal is high and narrow and its anterior opening has assumed a cordate outline. The neural spine is inclined strongly backward, much more so than that of the seventh cervical, and though laterally compressed it is extremely high, broad and massive, greatly exceeding in all its dimensions that of the last neck vertebra.

The anterior six thoracic vertebræ (see Pl. XVIII, Fig. 5) are very much alike in appearance. The first three have broader and more depressed centra, which in the others become deeper vertically and more trihedral in section. The transverse processes are very large and prominent and carry large, deeply concave facets for the rib tubercles. The neural spines are very high, thick and heavy, and are strongly inclined backward, with club-shaped thickenings at the tips. At the seventh thoracic begins a rapid reduction in the length and weight of the spines, a process which reaches its culmination on the eleventh vertebra, which has a remarkably short, weak and slender spine. This arrangement results in a great hump at the shoulders, somewhat as in *Titanotherium*, though in a less exaggerated form. In both genera, the length of the anterior thoracic spines should be correlated with the great elongation and weight of the skull which requires immense muscular strength in the neck and shoulders. *Hippopotamus* has no such hump, but this is probably explained by its largely aquatic habits.

A change in the character of the facets for the rib tubercles occurs simultaneously with the shortening of the neural spines; they suddenly become much reduced in size and are plane instead of concave. The transverse processes, however, remain very large and prominent as far back as the eleventh thoracic. In no case are these processes perforated by vertical canals, such as occur in *Sus*. The twelfth thoracic is the anticlinal vertebra and has a nearly erect spine of lumbar type, though somewhat more slender than in the true lumbar. On the thirteenth the spine is quite like that of the lumbar and inclines slightly forward. Transverse processes are absent from the last two thoracic vertebræ, which display the feature, very unusual in an ungulate, of large and conspicuous anapophyses.

As far back as the eleventh vertebra the zygapophyses are of the ordinary thoracic type; they are small, oval facets, the anterior pair on the front of the neural arch and presenting upward, the posterior pair on the hinder part of the arch and presenting downward. On the eleventh thoracic a change takes place; the anterior zygapophyses are as before, but the posterior processes are flat and present obliquely outward, rather than downward, the two together forming a prominent, wedge-shaped mass. The prezygapophyses of the twelfth vertebra are correspondingly modified; they present obliquely inward and together constitute a cavity which receives the wedge-like projection from the eleventh. Prominent metapophyses also make their appearance on the twelfth thoracic. The posterior zygapophyses of the latter and both pairs of the thirteenth are of the cylindrical, interlocking type characteristic of the lumbar. These processes are remarkably complex and in a fashion that does not occur in *Hippopotamus*, but is found in *Sus* and many of the Pecora. The complexity is occasioned by the development of large episphenial processes, which give an additional articular surface above the zygapophyses proper; in section these processes have an S-like outline, and they constitute a joint of great strength.

The *lumbar vertebræ* (Pl. XVIII, Fig. 6), almost certainly six in number, have rather short, but massive centra. In the anterior part of the region the centra are somewhat cylindrical in shape, but they become more and more depressed and flattened as we approach the sacrum. The neural canal is broad and very low, especially in the posterior part of the region. The neural spines are inclined forward and are of moderate height; they are broad antero-posteriorly, but thin and laterally compressed, except at the tips, where they are thickened. The spine of the last lumbar is a little different from the others in being more erect and slender. Episphenial processes are present on the first, second and sixth vertebræ, but not on the third, fourth or fifth. These processes are apt to be somewhat asymmetrical and better developed on one side than on the other, and it is probable that more extensive material would show them to be subject

to much individual variation. Metapophyses are prominent only on the first and second lumbar, rudimentary on the third and absent from the others. The transverse processes are very feebly developed in proportion to the size of the vertebræ. On the first lumbar they are short and straight, and gradually increase in length up to the fifth, but in all they are strikingly thin and slender. The last lumbar has transverse processes of unusual length, space for them being obtained by the sudden eversion of the anterior ends of the ilia, but even here they are weak.

The trunk-vertebræ of *Hippopotamus* are much more massively constructed than those of *Elotherium*, the decrease in length of the thoracic spines posteriorly is more gradual, while the neural spines and transverse processes of the lumbar are much longer and in every way heavier. The thoraco-lumbar series of *Sus* bears considerable resemblance to that of *Elotherium*, but in the former the transverse processes of the thoracic vertebræ are perforated by vertical canals, and those of the lumbar are much longer and stouter.

The *sacrum* consists of two vertebræ only. The first has a broad, depressed centrum and very large pleurapophyses, which carry most of the weight of the ilia, though the second sacral has also a limited contact with the pelvis. On the first vertebra the prezygapophyses are very well-developed and have large episphenial processes to receive those of the last lumbar. The two neural spines are coëssified into a high but short ridge. The second sacral has a very much smaller and especially a narrower centrum than the first, and retains moderately complete postzygapophyses.

In *Hippopotamus* and in *Sus* the sacrum is relatively much larger than in *Elotherium*, and consists of at least four vertebræ, sometimes even as many as six. Even in aged individuals of the White River genus I have not seen more than two vertebræ in the sacrum.

The *caudal vertebræ* (Pl. XVIII, Figs. 7, 8, 9), of which fifteen are preserved in association with one individual, indicate a tail of only moderate length, and present a number of peculiarities. The first caudal has somewhat the appearance of a miniature lumbar; its centrum is short, broad and depressed, with quite strongly convex faces; the neural canal is relatively large and a distinct, though small, neural spine is present. The zygapophyses, especially the anterior pair, are large and prominent and project much in front of and behind the centrum. The transverse processes are quite long and heavy, and are directed outward and backward. A pair of tubercles on the ventral side of the centrum represent rudimentary hæmapophyses.

The succeeding caudal vertebræ resemble the first in a general way, but passing backward, the centra become more and more slender and elongate, while the neural canal diminishes in size, and the various processes are reduced. The hæmapophyses, on the

other hand, increase in size and on the (?) fifth vertebra they curve toward each other, almost meeting and enclosing a canal, which continues as far back as the (?) eighth vertebra, behind which the hæmapophyses are again reduced. The middle portion of the tail is composed of very long, cylindrical vertebræ, which in shape strikingly resemble those of the great cats, and which are proportionately much longer, though apparently less numerous than those of *Anoplotherium*. At the anterior end of each vertebra are six prominent, nodular processes, the zygapophyses, transverse processes and hæmapophyses respectively. Posteriorly the centra become more and more slender, but are not much diminished in length, for what appears to be the penultimate vertebra is nearly as long as those in the middle region. The various processes are, however, reduced to very insignificant proportions. The last vertebra has its anterior portion shaped like that of its predecessor, but it rapidly tapers behind to a smooth, slender, compressed and subcylindrical rod, with a club-shaped thickening at the end. As I have seen but a single specimen of this curious vertebra, I cannot feel quite confident that its shape is a normal one and not due to some injury or morbid process.

The tail of *Hippopotamus* is of about the same relative length as that of *Elotherium*, but the individual vertebræ are very different, being all shorter and heavier, and diminishing in size more gradually to the end. In *Sus* the caudal vertebræ are somewhat more like those of *Elotherium*, but none of them have such slender elongate centra. Little is known concerning the caudals of *Anthracotherium*. Kowalevsky says of them: "Von den Schwanzwirbeln liegt mir nur ein einziges vor. Obwohl seine Erhaltung sehr mangelhaft erscheint, kann man doch aus diesem kleinen Stück den Schluss ziehen, dass der Schwanz bei den Anthracotherien kurz war und somit gar keine Aehnlichkeit mit dem sonderbar langen Schwanze der Anoplotherien hatte" ('73, p. 333; Taf. x, Fig. 36). The vertebra described by Kowalevsky is an anterior caudal and is much smaller and in every way more reduced than the corresponding ones of *Elotherium*. Among existing artiodactyls, it is the giraffe which most resembles the White River genus in the peculiar character of its caudal vertebræ.

Measurements.

Atlas, length.....	0.160
Atlas, greatest width.....	.270
Axis, length of centrum.....	.085
Axis, length of odontoid.....	.026
Axis, anterior breadth.....	.109
Axis, posterior breadth.....	.054
Third cervical, length.....	.066
Seventh cervical, length.....	.056
First thoracic, length.....	.051

Measurements.

Fifth thoracic, height of neural spine. ....	.291
First lumbar, length.....	.050
Sixth lumbar, length.....	.048
Sixth lumbar, breadth across transverse processes..	.176
Sacrum, length.....	.098
First sacral, width of centrum.....	.068
Second sacral, width of centrum.....	.025
Anterior caudal, length.....	.032
Median caudal, length .....	.063

V. THE RIBS AND STERNUM.

The *ribs* of *Elotherium* are decidedly smaller and lighter and indicate a less capacious thorax than we should expect to find in such a large animal, a fact which adds to the apparent height of the skeleton, because of the long interval between the thorax and the ground.

The first rib is short, subcylindrical proximally, but broadening considerably at the distal end; it has only a slight lateral curvature, appearing nearly straight when viewed from the front, but it arches moderately backward. The head is large and compressed, and is separated by a deep and narrow notch from the very large and conspicuous tubercle, which is also compressed laterally. The ribs increase gradually in length up to the seventh or eighth of the series, and the posterior five, though successively shortening, retain a considerable relative length throughout. The first five or six ribs are laterally compressed and of moderate breadth, but the posterior part of the thorax is composed of very slender and subcylindrical ribs, very different from those which we find in most ungulates, except in the more primitive groups. The tubercle reaches its maximum of size and prominence on the third rib, behind which it gradually diminishes in size and becomes more and more widely separated from the head, and more sessile in position. On the twelfth and thirteenth pairs the tubercles are absent, corresponding to the lack of transverse processes on the twelfth and thirteenth thoracic vertebræ.

In *Hippopotamus* the ribs are relatively very much longer, broader and heavier than those of *Elotherium*, and grow broader toward the hinder end of the thorax, where the great bony slabs are in the sharpest possible contrast to the slender and subcylindrical rods of the extinct genus. In *Sus* the ribs are more like those of *Elotherium*, but they have not such a regular and symmetrical curvature as in the latter.

The *sternum* of *Elotherium* is a very remarkable structure, and although it is of distinctly suilline type, it is, nevertheless, not altogether like the sternum of any known genus, recent or fossil. The presternum, or manubrium, forms a very large, thin, compressed and keel-shaped plate, which is especially remarkable for its great vertical depth,

this dimension exceeding the antero-posterior length, and is proportionately much greater than in *Hippopotamus* or the modern suillines. The body of this segment is extremely thin, but the anterior border, and to some extent the ventral border also, is thickened and rugose. The facets for the first pair of sternal ribs form prominences, which are situated near together and close to the postero-superior angles of the segment, so that nearly the entire length of the latter projects in front of the first pair of ribs.

Of the mesosternum four segments and a part of the fifth are preserved. The first segment somewhat resembles the presternum in shape, being short, narrow and very deep; the dorsal border is much thicker and wider than any other part of the segment, and the ventral border is also thickened, though in a less marked degree. Posteriorly, this element becomes somewhat wider and shallower. The second segment of the mesosternum is decidedly broader and shallower than the first, but still retains a very unusual degree of vertical depth. Both the dorsal and ventral surfaces are much broadened, while the body of the bone is a thin, vertical plate, which connects the horizontally directed dorsal and ventral borders, giving a cross-section somewhat like that of an I-beam. In the third segment these progressive changes are carried still farther, and the bone becomes very distinctly broader and lower than the second segment. The dorsal and ventral borders still project much beyond the vertical connecting plate; this plate, however, is much thicker transversely than in the preceding segment. The ventral surface is rendered quite strongly concave by the elevation of its lateral borders. In part, this concavity may be due to the pressure which has somewhat distorted the entire sternum, but the ventral groove is so symmetrical that it can hardly be altogether due to distortion. The fourth and fifth segments exhibit similar changes, each one being broader and lower than the one in front of it; the vertical plate becomes very much thicker and the ventral groove more widely open. Though the specimen is of an animal past maturity, yet the last three segments distinctly show the median suture, along which their lateral halves united.

In *Hippopotamus* the breast-bone is quite like that of *Elotherium*, but the presternum is longer and not of such exaggerated depth, and the rib-facets are placed much nearer to the anterior end, while the mesosternum consists of fewer, broader and shallower segments. In *Sus* the sternum is still more like that of *Elotherium*, but has a decidedly longer and lower presternum.

VI. THE FORE LIMB.

The fore limb of *Elotherium* is quite elongate and, in connection with the shallow thorax, and very long neural spines of the anterior thoracic vertebræ, it gives to the skeleton a somewhat stilted appearance.

The *scapula* is remarkably high, narrow and slender, at least in the White River species, while in the John Day forms there is reason to believe that its proportions are quite different. The glenoid cavity forms a narrow, elongate oval, with its long axis directed antero-posteriorly, and is not very deeply concave. The coracoid is a large, but not very conspicuous rugosity, which sends off from its inner side a compressed, hook-like process; when the shoulder-blade is seen from the external side, this process is concealed from view. The neck of the scapula is broad and rather thick, and there is no distinct coraco-scapular notch. The coracoid border in its upward course inclines forward but little, and for the upper one-third of its height curves gently backward, to join the suprascapular border, which is exceedingly short. The glenoid border is more oblique, and inclines backward and upward at a moderate angle. The spine is shifted far forward, dividing the blade very unequally, so that the prescapular fossa is very much smaller than the postscapular. Indeed, the distal one-third of the shoulder-blade can hardly be said to have any prescapular fossa at all. The spine itself is rather low, and for much of its course its free border is curved backward and thickened to form a massive metacromion. The acromion is very short and inconspicuous, ending considerably above the level of the glenoid cavity.

The scapula associated with the large species of *Elotherium* from the John Day beds, which Cope has described under the name of *Boöchaerus* ('79, p. 59), is very different in shape from that of *E. ingens* from the White River, to which the description in the preceding paragraph more particularly applies. The blade is very much broader, both fossæ widening rapidly toward the dorsal end; these fossæ are of nearly equal width and the spine is placed almost in the middle of the blade. There can be little doubt that this scapula is properly referred to the incomplete skeleton with which it was found associated. Aside from its similarity in color and texture to the rest of the skeleton, there is no other animal known from the John Day horizon to which so large a scapula could belong.

The shoulder-blade of *Hippopotamus* is much broader, in proportion to its height, than that of *E. ingens*; the coracoid is more prominent and the coraco-scapular notch is distinctly marked; the postscapular fossa is somewhat larger than the prescapular, but the difference is much less extreme than in the White River species, the spine occupying a more median position; the acromion is much the same in the two forms, but the metacromion is larger in the fossil. In *Sus* also the scapula is relatively broader than in *E. ingens*, and, in particular, it has a wider prescapular fossa, but is without any distinct coraco-scapular notch. The spine rises from the suprascapular border very steeply to the high (but much smaller) metacromion, and then descends gradually to the neck, without forming an acromion. In spite of these differences, the resemblance in the character of the scapula between *Sus* and *Elotherium* is unmistakable.

The *humerus* is relatively long, but is, at the same time, a massively constructed bone. The head is large and very strongly convex, especially from above downward, although it is not set upon a very distinct neck, nor does it project far behind the plane of the shaft. The external tuberosity is very large, forming a massive and roughened ridge, which runs across the whole anterior face of the head and rises toward the internal side, where it terminates in a high, thick and recurved hook, overhanging the bicipital groove. The internal tuberosity is very much smaller, but is, nevertheless, quite prominent; it likewise projects over the bicipital groove, which is very broad and deeply incised into the bone. The great transverse breadth of the external tuberosity displaces the groove far toward the internal side of the humerus. The shaft is long and heavy; its proximal portion has a great antero-posterior diameter, and its transverse thickness, though less, is still very considerable. The fore-and-aft diameter gradually diminishes downward, until the shaft assumes an almost cylindrical shape, below which point it begins to expand transversely. The deltoid ridge is rugose and prominent, and runs far down upon the shaft, but forms no deltoid hook. The distal end of the shaft is very heavy, being both broad and thick. The supratrochlear fossa is low, wide and shallow, while the anconeal fossa is very high, narrow and deep, its depth being much increased by the great production of the posterior angles of the distal end. The supinator ridge is rough, heavy and prominent. The trochlea, which is very completely modernized, in correspondence with the advanced differentiation of the ulna and radius, is somewhat obliquely placed with reference to the long axis of the shaft, descending toward the ulnar side. The trochlea differs very markedly from that of such primitive artiodactyls as *Oreodon* and *Anoplotherium*; it is high, full and rounded and is divided into two unequal radial facets, of which the inner one is decidedly the larger. The intercondylar ridge, which, in most primitive artiodactyls, forms a broad and rounded protuberance, is, in *Elotherium*, compressed into a sharp and prominent ridge, and shifted well toward the external side. The internal epicondyle, which is so largely developed in *Oreodon* and other early artiodactyls, has practically disappeared.

The humerus of *Hippopotamus* is relatively much shorter and more massive than that of *Elotherium*; the external tuberosity is not extended so far across the anterior face of the bone and the bicipital groove is, in consequence, not shifted so far toward the inner side; the deltoid ridge is much better developed and gives rise to a prominent deltoid hook. In the existing species of *Hippopotamus* the intercondylar ridge is narrower and less conspicuous, but in a Pliocene species from the Val d'Arno it has quite the same appearance as in *Elotherium* (see de Blainville, *Ostéographie*, *Hippopotamus*, Pl. V). The epicondyles are much more prominent than in the latter, and the postero-internal border of the anconeal fossa projects much more than does the

external border, while in *Elotherium* this difference is decidedly less marked. In *Sus* the humerus resembles that of the White River genus in form, but is proportionately very much shorter; the deltoid ridge is shorter and less prominent, while the supinator ridge and the epicondyles are more so.

The *radius* and *ulna* (Pl. XVIII, Fig. 10) are firmly coëssified in all the known species of *Elotherium*, though the suture between them is clearly marked, even in old animals. The radius is relatively very long, but rather slender; the head is quite thick, but of only moderate breadth, projecting most toward the external side. The humeral surface is composed of three connected facets, of which the internal one is much the largest and bears an elevated ridge for the corresponding depression on the humeral trochlea. The groove for the intercondylar ridge of the latter is quite broad and notches the anterior border of the radius. The shaft is rather narrow transversely, but quite thick and heavy, and arches forward but moderately; the distal portion is broadened and thickened and bears upon its dorsal face a deep tendinal sulcus, bounded by very prominent ridges. The distal face is quite broad, but without much dorso-palmar extension, and carries two well-distinguished carpal facets, which pursue an oblique course, from before backward and inward. The scaphoidal facet, which is the smaller of the two, is concave in front, saddle-shaped behind, and is reflected up upon the posterior face of the bone. The facet for the lunar is much larger than that for the scaphoid, and has a somewhat similar shape, but the anterior concavity is not so deep, and the articular surface is carried much farther up upon the palmar side of the radius. The radius has no contact with the pyramidal.

In *Hippopotamus* the forearm bones are ankylosed, though somewhat less intimately than in *Elotherium*. The radius is very short, broad and thick, and is almost straight. The external facet for the humerus is larger and more concave and the carpal facets are of more nearly equal size, while that for the lunar rises much more steeply toward the ulnar side. In *Sus* the two bones are separate, and the radius is short, very heavy and arched forward; its distal end is much more thickened than in *Elotherium*, the facet for the scaphoid is relatively larger, while that for the lunar is smaller and is extensively reflected upon the palmar face of the radius. In *Dicotyles* the ulna and radius have coalesced even more completely than in *Elotherium*.

The *ulna* has a very long, thick and prominent olecranon, which projects far behind the plane of the shaft. The process is convex on the outer side and concave on the inner, thickened and club-shaped at the free end, which displays a broad, shallow sulcus for the extensor tendons. The sigmoid notch is deep and the coronoid process prominent, as is required by the great depth of the anconeal fossa on the humerus. The articulation of the ulna with the latter is confined to the posterior and superior aspects of the humeral

trochlea, no part of the articular surface on the ulna presenting proximally, for the radius occupies the entire distal aspect of the humerus. Only the proximal portion of the facet for the humerus extends across the entire breadth of the ulna; for the rest of its course this facet is confined to the inner side. The shaft of the ulna is somewhat reduced, but is not interrupted at any point and, indeed, it is quite stout for its entire length; its principal diameter is the transverse, the antero-posterior thickness being decidedly diminished. Below the head it narrows and then expands to its maximum breadth, from which point it narrows gradually to the distal end. On its external side the shaft is quite deeply channeled. The distal end is small and bears a saddle-shaped facet for the pyramidal, which is concave transversely and convex in the dorso-palmar direction; its external border is compressed and extends as a sharp edge behind the body of the bone, forming a concavity on the palmar face. The pisiform facet is continuous with that for the pyramidal. The ulna extends distally below the level of the radius and thus arises the very exceptional condition of an articulation between the ulna and the lunar. The facet for this carpal element is small and is entirely confined to the radial side of the ulna, the distal end of the latter not extending at all upon the proximal face of the lunar. In most artiodactyls in which the functional digits have been reduced to two, the radius tends to encroach more or less extensively upon the proximal face of the pyramidal, for which extension the diminution of the ulna makes a way. In *Elotherium* the arrangement is different, the ulna occupying the entire proximal surface of the pyramidal, and by extending below the level of the radius securing a lateral contact with the lunar. Indeed, this arrangement quite precludes the attainment of the more usual radial-pyramidal articulation.

The ulna of *Hippopotamus* is proportionately much shorter and in every way more massive than that of *Elotherium*; it also has a very much larger and more prominent olecranon, as would naturally follow from the immensely greater weight of body which requires support upon the limbs. There appears to be a slight disto-lateral contact between the ulna and the lunar; at all events, the radius does not extend over upon the pyramidal. In *Sus* the ulna is free throughout and its shaft is relatively much shorter and heavier than in *Elotherium*; the ulna and lunar do not come into contact. The ulna of *Dicotyles* is more reduced than that of the White River genus and the connections of the carpals with one another and with the metacarpus are upon quite a different plan.

Measurements.

Scapula, height.....	0.430
Scapula, greatest width.....	.245
Scapula, breadth of neck .....	.065
Scapula, glenoid cavity, ant.-post. diameter.....	.068

Measurements.

Scapula, glenoid cavity, transverse diameter.....	.050
Humerus, length.....	.405
Humerus, width of proximal end.....	.132
Humerus, thickness of proximal end.....	.128*
Humerus, width of distal end.....	.095
Radius, length.....	.350
Radius, width of proximal end.....	.074
Radius, width of distal end.....	.062
Ulna, length.....	.413
Ulna, length of olecranon fr. coronoid process.....	.103
Ulna, width of distal end.....	.037

VII. THE MANUS (Pl. XVIII, Fig. 11).

The principal facts of the structure of the fore foot have already been determined by Kowalevsky, but the material now at command permits a more complete account to be given. Certain differences also which obtain between the European and American representatives of the genus should not be passed over without mention.

The *carpus* of *Elotherium* is a curious one in many ways, and while modified to suit the didactyl condition of the foot, by the reduction of the lateral and enlargement of the median elements, it has yet retained many of its primitive characteristics.

The *scaphoid* is high and thick in the dorso-palmar direction, but very narrow transversely. The dorsal and internal (*i. e.*, radial) surfaces of the bone are very rugose, and on the palmar border, which is the narrowest part of the scaphoid, is a blunt and massive mammillary process. The articular surface for the radius is of unusual shape. It is divided into two parts, an antero-external and a postero-internal; the latter is much the larger and is saddle-shaped, convex transversely and concave in the dorso-palmar direction, while the former is convex and descends steeply toward the ulnar side. These two parts of the articular surface are continuous, but they meet at nearly a right angle, and their junction forms a ridge, which is the highest point of the scaphoid. On the ulnar side are three facets for the lunar; the largest one is proximal and dorsal, and is continuous with the surface for the radius, which it meets at almost a right angle; this facet is very oblique and presents distally as well as laterally, the scaphoid here forming a projection which extends over the lunar. The second lunar facet is dorsal and distal in position; it is small, nearly plane, and not very distinctly separated from the facet for the magnum. The third lunar facet is distal and palmar, and is placed upon the ulnar side of the mammillary process already mentioned; it is of oval shape and nearly flat. The contact between the scaphoid and the lunar is confined to these three points, and as the

* Somewhat reduced by crushing.

facets on both bones are more or less prominent, they are elsewhere separated by considerable interspaces. The distal side of the scaphoid is much narrower than the proximal and is occupied by facets for the trapezoid and magnum, no articular surface for the trapezium being apparent. The trapezoidal facet is considerably the smaller of the two, and is simply concave. The magnum facet is in two parts, a very slightly concave distal portion, and a somewhat smaller lateral portion on the ulnar face of the scaphoid.

In the European species figured by Kowalevsky ('76, Taf. XXVI) the scaphoid is somewhat broader than in the American forms. In both groups a remarkable resemblance to the scaphoid of *Anthracotherium* is observable, which extends to even the details of structure (see Kowalevsky, '73, Taf. XI, Fig. 38). As *Anthracotherium* is, however, a tetradactyl form, the scaphoid is somewhat broader in proportion to its height than that of *Elotharium*, though hardly so much so as would be expected. In *Hippopotamus* and *Sus* the scaphoid is of quite a different shape from that of the fossils, being distinctly shorter and wider.

The *lunar* is a very large and complex carpal, which exceeds the scaphoid in all of its dimensions, and especially in breadth. The radial facet is in two parts, continuing those which occur on the scaphoid; the anterior or dorsal part extends across the width of the bone and is very convex antero-posteriorly, while the palmar portion is very much larger and is concave in the same direction. The dorsal border rises steeply toward the ulnar side, where the lunar is drawn out into a blunt, projecting, hook-like process, which extends over the pyramidal, as the scaphoid does over the lunar. On the radial side are three facets for the scaphoid, corresponding to those on the latter, which have already been described. The palmar face is greatly extended transversely, and, though lower, is much broader than the dorsal surface. On the ulnar side are two facets for the pyramidal, which constitute an interlocking joint of unusual firmness and strength. One of these facets is proximal and dorsal and overlaps the pyramidal; the second, which is very much larger, is palmar and distal in position, and has a saddle-like shape; it interlocks closely with a similar facet upon the pyramidal. When seen from the front, the contact between the lunar and the magnum appears to be entirely lateral, but as it passes toward the palmar side, the magnum facet broadens, becomes very concave, and assumes a distal position. The unciform facet is also oblique and the beak between the two is not in the median, but shifted far toward the radial side. Dorsally the unciform facet is considerably wider than that for the magnum, but on the palmar side these proportions are reversed.

The lunar of *E. magnum* figured by Kowalevsky resembles that of *E. ingens*, except that its proximal surface does not rise so steeply toward the ulnar side and does not

project over the pyramidal. The lunar of *Anthracotherium* (see Kowalevsky, '73, Taf. XI, Fig. 37) is like that of *Elotherium*, but is narrower, especially its palmar face, and much thicker, and the distal beak is more nearly in the median line. In *Hippopotamus* the lunar is broad and rests almost equally upon the magnum and the unciform, as it does also in *Sus*.

The *pyramidal* quite resembles the scaphoid in shape, but is much broader, not so thick antero-posteriorly, and generally of a more rugose and massive appearance. In view of the reduced lateral digits and the coössified radius and ulna, the relatively large size of the pyramidal is somewhat surprising. The proximal end is occupied by the ulnar facet, which is convex transversely and deeply concave antero-posteriorly. On the palmar side is a narrow, plane facet for the pisiform, which is very oblique in position. This facet is carried upon a compressed and slightly recurved, hook-like ridge, which runs for nearly the full vertical height of the bone, though not quite reaching to the distal end. On the radial side are two facets for the lunar, separated by a wide and deep sulcus; the palmo-distal one is larger than the corresponding surface on the lunar, and its curvatures are, of course, in opposite directions to those of the latter, being concave in the vertical, and convex in the dorso-palmar diameter. The distal end of the pyramidal is taken up by a large, but slightly concave facet for the unciform.

In the material described by Kowalevsky the pyramidal of *Elotherium* is not represented, while that of *Anthracotherium* is so badly preserved and of such uncertain reference, that any comparison founded upon it would be valueless. The pyramidal of *Hippopotamus* is broad, square and heavy, as is also that of *Sus*, on a smaller scale.

The *pisiform* is quite small and slender, though of considerable length; it is strongly recurved toward the median side of the carpus, presenting the convexity externally; the distal end is thickened and club-shaped, though but little expanded in the vertical dimension. The pyramidal facet is nearly plane and oblique in position, broadest externally and narrowing to a point on the radial side. The ulnar facet is very much smaller and somewhat concave; the two meet at almost a right angle.

The pisiform of *E. magnum* (Kowalevsky, '76, Taf. XXVI, Fig. 27) is not unlike that of *E. ingens*, but is of a more irregular shape, which looks as though it might be due to disease, that of *Anthracotherium* (Kowalevsky, '73, Taf. XI, Fig. 58) is of quite similar shape, though much larger. In *Sus* the pisiform is of an entirely different shape from that of either of the extinct genera, being much deeper vertically, more compressed and plate-like, and less strongly recurved. That of *Hippopotamus* is more like that of the fossil forms.

The *trapezium* is not associated with any of the specimens which I have seen, nor is any facet for it distinctly visible on either the scaphoid or the trapezoid. If present at

all, it must have been in a very reduced and rudimentary condition, having lost all functional importance.

The *trapezoid* is high, narrow and thin ; it is closely interlocked with the magnum, lying in a depression on the radial side of that bone. The facet for the scaphoid is simple and strongly convex. Three facets for the magnum occur on the ulnar side, one proximal and two distal ; the former is much the largest of the three, but is confined to the dorsal part of the ulnar side. Of the two distal facets, one is dorsal and one palmar ; they are separated by a narrow space and are situated in different planes, almost at right angles to each other. On the radial side, near the distal end, is a shallow depression, which may have lodged a rudimentary trapezium, though there is no facet for such a bone. The distal side of the trapezoid bears a small, plane facet, of triangular shape, for the rudimentary second metacarpal.

The trapezoid is not yet known in connection with the European species of *Elotherium*, or with *Anthracotherium*. In *Hippopotamus* it is lower and broader and of more functional importance than in *Elotherium*, as it also is in *Sus*, and in the latter, differing from all of the other genera mentioned, it articulates extensively with the third metacarpal.

The *magnum* is a relatively large and massive bone, the three diameters of which are nearly equal, though the dorso-palmar dimension somewhat exceeds the other two. The dorsal moiety of the bone is the lower, quite a prominent head rising proximally from the palmar portion. The palmar hook is represented by a short, but broad, rough and massive ridge. The proximal end is unequally divided between the facets for the scaphoid and lunar ; dorsally the former is much the wider and occupies almost the entire breadth of the bone, but it does not extend so far posteriorly and on the head is confined to the antero-internal aspect of that elevation. The lunar facet is very narrow on the dorsal side, and lateral rather than proximal in position, but posteriorly it widens and covers nearly the entire head. When viewed from the ulnar side, the lunar facet appears to be of a horseshoe-shape, narrow arms extending far down upon the dorsal and palmar borders, and separated below by a very large sulcus. These two arms of the lunar facet are obscurely demarcated from the two small facets for the unciform, in which they may be said to terminate distally. The distal end of the magnum is covered by the large, saddle-shaped surface for the third metacarpal, which is convex transversely and concave antero-posteriorly ; and proximal to this, on the radial side, is a small facet for the second metacarpal. On the radial side also is a depression, running almost the full vertical height of the magnum, for the reception of the trapezoid. The depression contains a larger proximal and two smaller distal facets for the trapezoid, corresponding to those already described on the latter.

The magnum figured by Kowalevsky ('76, Taf. XXVI, Figs. 21, 32) is of the same general type as in the American species, but with some differences of detail. Thus, the bone is of relatively greater antero-posterior thickness; the palmar face is narrower and the palmar hook very much more prominent; the sulcus which, on the ulnar side, separates the two arms of the lunar facet is much narrower, and, in consequence, the arms themselves are broader; the head of the magnum rises less abruptly toward the palmar side. The magnum of *Anthracotherium* is not sufficiently well known for comparison. That of *Hippopotamus* is low and broad, and differs from the magnum of *Elotherium* in that the dorsal portion of the lunar facet is proximal in position. In *Sus* also the magnum is low and wide; its lunar facet is relatively larger than in *Hippopotamus*, and it has no articulation with the second metacarpal, from which it is excluded by the contact of the third metacarpal with the trapezoid; the head is low.

The *unciform* is the largest and most massive bone of the carpus; in shape it is low, broad and thick, with its principal diameter directed transversely, and has on the palmar side a hook-shaped process, which is not very prominent, but broad and heavy. The proximal end is occupied by the facets for the lunar and pyramidal, of which the latter is much the wider; the junction of the two forms a prominent ridge which curves across the proximal end, from the dorsal to the palmar side. These two facets are both slightly concave transversely, but very strongly convex antero-posteriorly, being reflected far down upon the palmar face. On the radial side are two vertical articular bands, separated by a wide and deep sulcus. The dorsal band, which is much the wider of the two, is composed of two very obscurely separated facets, a minute proximal one for the magnum and a very large distal one for the unciform process of the third metacarpal. The palmar band is a high and narrow facet for the magnum only, and is much more extended vertically than the corresponding surface on that bone. The distal end carries a large facet for the head of the fourth metacarpal, and on the ulnar side is a minute facet for the rudimentary fifth metacarpal.

The unciform of Kowalevsky's specimen does not differ in any significant way from that of the American species. In *Anthracotherium* this bone is much wider and lower than in *Elotherium* and the facet for the fifth metacarpal is more distal than lateral. In *Hippopotamus* the unciform is exceedingly large, and its dorsal face is of a low, wide, rectangular outline, and its great breadth corresponds to the large size and functional importance of the fifth metacarpal. The proximal end is divided almost equally between the lunar and pyramidal facets, and the absence of a distal beak on the lunar allows a larger contact between the unciform and magnum. In *Sus*, which has much reduced lateral digits, the unciform is narrower than in *Hippopotamus*, but broader than in *Elotherium*, and the facet for the fifth metacarpal is not so completely displaced toward the ulnar side as in the latter.

The *metacarpus* consists of four members, two functional, the third and fourth, and two mere rudimentary nodules, the second and fifth.

Metacarpal II is not preserved in any of the specimens which I have seen, though it is figured by Marsh ('93, Pl. VIII, Fig. 4), but the facets on the neighboring bones show that it was carried by the trapezoid and retained a lateral connection with the magnum, excluding mc. iii from any contact with the trapezoid. The manus of *Elotherium* is thus a typical example of what Kowalevsky has called the "inadaptive mode" of digital reduction.

Metacarpal III is long and massive. The head is heavy, enlarged in both dimensions, and has a stout prominence upon the palmar side; it bears a broad, saddle-shaped surface for the magnum. On the radial side is a depression for mc. ii, at the proximal end of which are two small facets for that bone. The unciform process is very large, prominent and heavy, and projects far over the head of mc. iv, but is, as usual, confined to the dorsal half of the head. On the distal side of this process and on the ulnar side of the shaft is a continuous, concave facet for the head of mc. iv. A second facet for the same metacarpal is borne upon the palmar projection from the head. The shaft of mc. iii is broad, but much compressed and flattened antero-posteriorly; both width and thickness are nearly uniform throughout, but increase slightly toward the distal end. The distal trochlea is broad and rather low, but is reflected well up upon the palmar face; on the dorsal side it is demarcated from the shaft only by an obscure ridge, with no deep depression above it. The carina is very prominent, but is confined entirely to the palmar face. The lateral pit on the ulnar side is large and deep, but that on the radial side is faintly marked.

In Kowalevsky's specimen ('76, Taf. XXVI, Fig. 21) the third metacarpal does not differ in any important way from that of the American species, though the magnum facet is somewhat more concave transversely and the shaft is rather more slender. In *Anthracotheurium* (Kowalevsky, '73, Taf. XIII, Fig. 80) mc. iii is very similar to that of *Elotherium*, but is relatively heavier; at the proximal end the tubercle for the insertion of the extensor carpi radialis muscle is more conspicuous, and the palmar projection of the head more prominent.

Metacarpal IV is a little shorter and narrower than mc. iii, with which it articulates by two large facets, separated by a wide and deep groove; of these facets the dorsal one, which is overlapped by the unciform process of mc. iii, is strongly convex, while the palmar facet is flat and borne upon the palmar projection. The ulnar side has a shallow groove, in which lies the nodular mc. v; the articulation with the latter is by means of a single, small, triangular facet. The shaft is somewhat narrower transversely than that of mc. iii, but is otherwise like it, as is also the distal trochlea.

In *E. magnum*, Kowalevsky's figure shows a somewhat differently shaped proximal end ('76, Taf. XXVI, Figs. 21, 24), the head is somewhat more extended transversely, especially toward the ulnar side, while the palmar projection is narrower and less prominent. In *Anthracotherium* the head of mc. iii has no such transverse extension.

Metacarpal V is an almond-shaped nodule, almost exactly like the specimen figured by Kowalevsky (Taf. XXVI, Fig. 25), though of a rather more regular outline. Proximally the nodule has quite a large, subquadrate, and slightly concave facet for the unciform, which presents more laterally than superiorly, and forming a very obtuse angle with this surface, is a smaller, triangular facet for mc. iv.

The metacarpus of *Hippopotamus* has four functional members, though the median pair are longer and stouter than the lateral. Compared with those of *Elotherium* they are relatively shorter and much heavier. In *Sus* there are also four metacarpals, but the laterals are much reduced, while the median pair, which carry most of the weight, are very short and thick, and the distal carina surrounds the entire trochlea, dorsal as well as palmar. The mode of articulation between the carpals and metacarpals is quite different from that found in either *Elotherium* or *Hippopotamus*, the head of mc. iii being much broadened and articulating extensively with the trapezoid, so that mc. ii is cut off from any contact with the magnum. This is what Kowalevsky has called the "adaptive method" of digital reduction, and it is in decided contrast to the inadapative method exemplified in *Elotherium*.

The *phalanges*, which are quite short, as compared with the length of the metacarpals, are developed only in the median pair of digits. The proximal phalanx of digit iii is relatively elongate, straight, broad and depressed; its proximal end is both wide and thick, and carries a concave facet for the metacarpal trochlea, which is deeply notched on the palmar border for the carina. Toward the distal end the phalanx narrows but little, though diminishing much in the dorso-palmar diameter; the distal trochlea is low, wide, depressed and only slightly notched in the median line. The second phalanx is short, broad and thick, and of quite asymmetrical shape; its proximal trochlea is obscurely divided into two facets, of which that on the radial side is the larger and extends more in the palmar direction, while the median dorsal beak is not prominently developed. The distal trochlea is much thicker than that of the first phalanx, is reflected much farther upon the dorsal face, and is more distinctly notched in the median line. The course of this surface is oblique, so that it faces somewhat to the ulnar side. The ungual phalanx is curiously small and nodular in shape, and is short, but quite broad and thick; the proximal trochlea is imperfectly divided into two slightly concave facets. The palmar surface is nearly plane, except for its rugosities, while the dorsal margin descends abruptly to the blunt distal end.

In *Anthracotherium* (Kowalevsky, '73, Taf. XI, Figs. 53, 54) the phalanges are of the same general type as in *Elotherium*, but are proportionately much shorter and stouter. In *Hippopotamus* they are short, broad and very heavy, while the unguals are reduced and of nodular form. In *Sus* the three phalanges of a digit are together considerably longer than the metacarpal, which is far from being the case in *Elotherium*; they are also of quite a different shape from those of the latter. The proximal phalanx is much thicker in proportion to its length, and its proximal trochlea is deeply grooved across its whole face for the metacarpal carina. The ungual phalanx is longer, broader and more depressed and pointed.

Measurements.

Carpus, height.....	0.072
Carpus, width.....	.077
Scaphoid, height.....	.038
Scaphoid, breadth.....	.026
Scaphoid, thickness.....	.047
Lunar, height.....	.047
Lunar, breadth.....	.036
Lunar, thickness.....	.050
Pyramidal, height.....	.033
Pyramidal, breadth.....	.027
Pyramidal, thickness.....	.039
Pisiform, length.....	.042
Trapezoid, height.....	.025
Trapezoid, breadth.....	.012
Trapezoid, thickness.....	.019
Magnum, height (excl. of head).....	.025
Magnum, breadth.....	.035
Magnum, thickness.....	.048
Unciform, height.....	.036
Unciform, breadth.....	.037
Unciform, thickness.....	.050
Metacarpal iii, length (in median line).....	.167
Metacarpal iii, width proximal end.....	.044
Metacarpal iii, width distal end.....	.039
Metacarpal iii, thickness proximal end.....	.039
Metacarpal iv, length.....	.161
Metacarpal iv, width proximal end.....	.038
Metacarpal iv, width distal end.....	.039
Metacarpal iv, thickness proximal end.....	.035
Phalanx 1, digit iii, length.....	.060
Phalanx 1, digit iii, width proximal end.....	.039
Phalanx 1, digit iii, width distal end.....	.032
Phalanx 2, digit iii, length.....	.048
Phalanx 2, digit iii, width proximal end.....	.031
Phalanx 3, digit iii, length.....	.028

VIII. THE HIND LIMB.

The *pelvis* is remarkable in many ways. As a whole, it is curiously long and narrow, except anteriorly, where the sudden and strong eversion of both ilia gives it considerable breadth. The ilium is elongate, and has a long, heavy, trihedral peduncle, which expands quite abruptly into the broad anterior plate. This plate is very strongly everted in its antero-inferior portion, and in shape is not at all like that of *Sus*, or of most existing artiodactyls, but rather resembles that of such ancient perissodactyls as *Palaeosyops*. The plate rises high above the sacrum and conceals much of that bone from view, when the pelvis is seen from the side; the gluteal surface is concave and the sacral surface strongly convex; the suprailiac border is quite thin for most of its course, but becomes very thick and rugose at its inferior angle. The iliac surface is relatively wide and may be traced through the whole length of the bone, the pubic border being very distinctly marked throughout. The ischial border is, for the most part, thick and rounded, but becomes sharp and compressed above the acetabulum. The pectineal process is a very prominent and rough tuberosity, and a second rugosity lies above and behind it. The acetabulum is rather small, but deep, and is of almost circular form; its articular surface is but little reduced by the deep and narrow sulcus for the round ligament.

The ischium is likewise elongate, though much shorter than the ilium; above the acetabulum its dorsal border arches upward into a high, thin and roughened crest, the ischial spine, very much like that seen in *Sus*, behind which is a distinct ischiadic notch, a difference from the true pigs, which have no such notch. For most of its length, the ischium is laterally compressed, but expands posteriorly into a large, thick plate, with everted hinder border and very massive tuberosity. The pubis is short, heavy and depressed. The symphysis, in which both the pubes and the ischia take part, is very long, the posterior notch between the two ischia being shallow. Consequently, the obturator foramen is much elongated antero-posteriorly, and of oval shape. This region of the pelvis is entirely different from that of *Sus*, in which the ischia are widely separated behind, the symphysis is short, and the obturator foramen is nearly circular in outline. In *Hippopotamus* the pelvis is more like that of *Elotherium*, but is much larger and more massive in every way; the peduncle of the ilium is not so elongate or so slender, the spine of the ischium is very much less prominent, and the posterior expansion of the ischium is very much larger and heavier. Unfortunately, the pelvis is not sufficiently well known in *Ancodus* or *Anthracotheirus* for comparison with that of *Elotherium*.

The *femur* is a long and proportionately rather slender bone. The proximal end is

quite widely expanded in the transverse direction; and in shape recalls that seen in the camels and llamas. The head is almost hemispherical in form and has a small, deep pit for the round ligament; it is set upon a very distinct neck, which is connected by a long, narrow bridge of bone with the great trochanter. The latter is very large and massive, especially in the antero-posterior direction, but does not rise above the level of the head, and hence is not very conspicuous, when the femur is seen from the front. The digital fossa is deep and widely open, which is due to the great thickness of the trochanter, but is not much extended in the vertical direction. The second trochanter is also large and very rugose, but not very prominent; it projects almost entirely backward, so that the trochanter is hardly visible, when the bone is viewed from the anterior side. There is no plainly marked intertrochanteric ridge, connecting the great and second trochanters, but from the latter a ridge runs proximally and almost reaches to the head.

The shaft of the femur, which in its proximal portion is much expanded transversely and compressed antero-posteriorly, rapidly narrows downward, and below the second trochanter becomes quite slender and subcylindrical in shape. Toward the distal end the shaft widens considerably, though increasing little in thickness. Above the external condyle is a long, narrow pit, with rugose margins, which serves for the origin of the plantaris muscle. The rotular groove is very broad, but quite shallow; its inner border is much thicker and more prominent than the outer, and ascends higher proximally, where it terminates in a short, overhanging hook, while the external border dies away more gradually. The condyles are relatively small; they present directly backward, though not projecting very strongly behind the plane of the shaft, and are of almost equal size, the external one but slightly exceeding the internal in height and breadth. The intercondylar fossa is broad and deep and has nearly straight borders.

The proportionately small antero-posterior diameter of the distal part of the femur in *Elotherium* is in decided contrast to the thickness of this region in *Ancodus*. The femur of *Anthracotheirus* is much like that of *Elotherium*, but it is even more slender in proportion to its length, and the condyles are smaller. *Sus* has a femur of quite a different type; the proximal end is not so wide, the head is more sessile and has a much larger pit for the round ligament; the bridge connecting the head with the great trochanter is shorter and much thicker, and the trochanter itself is more prominent; the shaft is relatively less elongate, the rotular groove has borders of nearly equal height, and the condyles are more prominent. The femur of *Hippopotamus*, though extremely massive, has yet a certain resemblance to that of *Elotherium*, as may be seen in the transverse expansion of the proximal end and in the obliquity and asymmetry of the rotular groove.

The *patella* is large, massive and of rather peculiar shape. It is high, quite broad

and thick in the middle portion, but with the distal part quite thin and narrow, and tapering to a blunt point; the proximal portion is also narrow and rises above the articular surface as a compressed, but thick and rugose process. The femoral surface is convex transversely, and only very obscurely divided into external and internal facets by a broad and low median ridge. This patella bears very little resemblance to the very thick knee-cap of *Ancodus* and still less to that of *Sus*. In the latter the patella is a short, rather narrow, but very thick bone, the posterior surface of which is of a regularly oval outline. *Hippopotamus* also has a patella which bears but little resemblance to that of *Elotherium*; it is short, but very broad and extremely thick, and sends off a long, horizontal process from the internal border.

The *tibia* is a massive bone, considerably shorter than the femur, but relatively heavier. The proximal end is very broad and thick; the condyles are of the usual saddle-shaped form and have a rather small antero-posterior extension; the inner condyle is somewhat more extended in this direction, while the outer one is wider transversely, and projects over the external side of the shaft. The fibular facet is small and is confined to the postero-external angle of the outer condyle. The tibial spine is low and bifid. The cnemial process is exceedingly heavy and prominent, and runs far down upon the shaft, extending for nearly half the length of the bone; its proximal portion displays a depression for the long patella, and the sulcus for the tendon of the extensor longus digitorum is deeply incised. The shaft of the tibia is heavy throughout, not diminishing much in diameter distally; it has a decided lateral and a slight anterior curvature. The distal end is quite broad, but not very thick, and has an unusually quadrate outline. The astragalar surface is divided by a low intercondylar ridge into two facets, of which the external one is much the larger and the inner one more deeply impressed. The intercondylar ridge, which pursues a very straight course across the distal end, is remarkable for its bifid termination at the anterior margin. A considerable sulcus is placed upon the intercondylar ridge, invading the articular surface on each side. On the external side of the distal end of the tibia is a broad, rugose depression for the fibula, but with only a very small external facet for the latter; an additional fibular facet forms a narrow band upon the *distal* surface, the tibia extending somewhat over this portion of the fibula. The malleolar process is short and compressed, and has no great antero-posterior extension.

The tibia of *Anthracotherium* (Kowalevsky, '73, Taf. X, Fig. 29) is much like that of *Elotherium*, but is relatively shorter and heavier. *Sus* also has a similar tibia, differing only in minor details. The tibia of *Hippopotamus* is of the same general type, but is extremely short and massive.

The *fibula* is complete and is not coössified with the tibia at any point, but is, never-

theless, very much reduced. The proximal end is laterally compressed and very narrow, but retains considerable antero-posterior extent, and bears a narrow, obliquely placed and slightly convex facet for the tibia. The shaft tapers and becomes exceedingly thin and delicate, though of very irregular shape; distally the shaft thickens much in the fore-and-aft diameter, but remains very narrow. The distal end forms a large external malleolus, but continues to be very narrow. The malleolus projects inward beneath the tibia and has a narrow facet which presents proximally and articulates with the facet, already mentioned, on the distal face of the tibia. The astragalar facet is quite large, extending for almost the whole thickness of the malleolus and curving downward in front; the calcaneal facet, which occupies the entire distal end of the fibula, is narrow, but has a very considerable antero-posterior extension. On the outer side of the malleolus are two deeply incised sulci for the peroneal tendons. In *Sus* the fibula is very much stouter and less reduced than in *Elotherium*, while the distal end is less enlarged and does not extend beneath the tibia. The fibula of *Hippopotamus* is relatively very slender, but it differs from that of the White River genus in having a smaller proximal and very much larger distal end.

Measurements.

Pelvis, length.....	0.495
Pelvis, antero-inferior breadth.....	.395
Pelvis, breadth at acetabulum.....	.191
Ilium, length.....	.280
Ilium, greatest width.....	.197
Ischium, length.....	.215
Obturator foramen, length.....	.094
Symphysis, length.....	.190
Femur, length.....	.405
Femur, breadth proximal end.....	.115
Femur, breadth distal end.....	.100
Femur, thickness distal end.....	.103
Femur, breadth of trochlea.....	.052
Patella, vertical diameter.....	.107
Patella, transverse diameter.....	.056
Tibia, length.....	.338
Tibia, breadth proximal end.....	.092
Tibia, breadth distal end.....	.063
Tibia, thickness proximal end.....	.088
Tibia, thickness distal end.....	.054
Fibula, length.....	.305
Fibula, breadth proximal end.....	.012
Fibula, breadth distal end.....	.016
Fibula, thickness proximal end.....	.023
Fibula, thickness distal end.....	.040

IX. THE PES.

The *tarsus* has undergone little specialization, although the hind foot, like the fore foot, is didactyl.

The *astragalus* is elongate, though broad and massive as well. The proximal trochlea is deeply but very broadly grooved and its two parts are unequal, the external condyle rising much more, both proximally and dorsally, than the internal, but not produced so far distally. While the outer condyle is widely separated from the cuboidal facet, the inner one is continued so far distally as to become confluent with the navicular surface. A very large and deep pit occupies a great part of the dorsal surface between the proximal and distal trochleæ. The distal trochlea is broad and is unequally divided into facets for the cuboid and navicular, the latter being much the wider and of a different shape. The surface for the cuboid is strongly convex in the dorso-plantar direction, but nearly plane transversely, while the navicular facet is hour-glass shaped, and on the fibular side of the median line has a distinct, though wide and shallow groove for a corresponding ridge on the proximal side of the navicular. The junction of the two facets forms a sharp but not prominent edge.

The facets for the calcaneum somewhat resemble those which we find in *Ancodus*, but they have not attained to such a degree of specialization as in the American species of that genus. The proximal external facet is divided by a sulcus into two parts, both of which are concave and present distally, as well as laterally. The proximal portion is set on a conspicuous prominence of the fibular side of the astragalus, and is clearly visible when the bone is seen from the dorsal side, while the distal portion is also prominent, but is concealed when looked at from the same point of view. The sustentacular facet is very large and is strongly convex in the proximo-distal direction, but almost plane transversely; its external border projects as a shelf beyond the body of the astragalus, and thus helps to enclose the large and deep sulcus which is found upon the external side of the bone. The distal external facet for the calcaneum is very small. The fibular facet is well extended in the proximo-distal diameter, but is narrow in the dorso-plantar direction.

In Kowalevsky's specimen ('76, Taf. XXVII, Fig. 34) the astragalus, so far as it is preserved, resembles that of the American species, but the external part of the proximal trochlea is too much damaged to show the characteristic external calcaneal facet. In *Anthracotherium* (Kowalevsky, '73, Taf. XI, Fig. 59, de Blainville, Ostéographie, Anthraco., Pl. II) the astragalus is proportionately much broader and lower than in *Elotherium*, the ridge on the distal trochlea, formed by the junction of the two facets, is more prominent and pursues a more oblique course. The sustentacular facet is narrower and shorter and the proximal calcaneal facet projects less. The astragalus of *Sus* is quite

like that of *Elotherium*, especially in the proportions of the distal trochlea. In *Hippopotamus* the astragalus is remarkable for its extreme shortness, for the asymmetry of its proximal trochlea, the outer condyle much exceeding the inner in size, and for the almost equal division of its distal trochlea between the navicular and cuboid facets.

The *calcaneum* has a long tuber, which is deeply channeled on the external side and for most of its length is compressed and rather slender, but swells at the free end into a massive, club-shaped expansion, which has a broad, shallow tendinal sulcus on the plantar face. From the free end the dorso-plantar diameter of the calcaneum increases gradually to the fibular facet, where it reaches its maximum, and from which it contracts rapidly toward the distal end. The sustentaculum is very prominent and bears a wide, slightly concave facet for the astragalus. The distal astragalar facet is much more extended in the dorso-plantar direction than is the corresponding surface on the astragalus and indicates an unusual amount of movement between the two bones. The cuboidal facet is narrow transversely, but much extended antero-posteriorly; it is divided, though very obscurely, into dorsal and plantar parts, of which the former is the larger and has something of a saddle-like shape, while the latter is smaller and concave.

Kowalevsky does not describe the calcaneum of *E. magnum* and his description and figures of *Anthracotherium* do not furnish data for comparison. The calcaneum of *Sus* resembles that of *Elotherium*, but is broader and has a tuber of more uniform thickness, not channeled on the outer side. The articular surface for the cuboid is very distinctly divided into two facets, the junction of which forms a sharp ridge. In *Hippopotamus* the calcaneum has an exceedingly long and massive tuber, which is greatly swollen at the free end.

The *navicular* is a large bone, not very broad, but of considerable dorso-plantar diameter. The surface for the astragalus is hour-glass shaped, with two concavities separated by a broad, convex ridge, which on the dorsal side is marked by an elevation of the proximal margin. The concavity on the tibial side is the larger of the two and its plantar border rises much higher than that of the external concavity. There are three facets for the cuboid on the fibular side of the bone, one plantar and two dorsal; the former is very strongly convex, projecting well outward, and is high vertically, but narrow antero-posteriorly. The two dorsal facets are both small and plane, and are placed at the proximal and distal margins of the navicular. The plantar hook is very much reduced, forming hardly more than a roughened ridge. The distal end is occupied principally by the large facet for the ectocuneiform, which extends across the whole dorsal side and much of the tibial side also. Partially separated from this is a minute surface for the mesocuneiform. The facet for the entocuneiform is much larger than the latter; it stands isolated at the postero-internal angle of the distal end and is somewhat saddle-shaped,

concave antero-posteriorly and convex transversely. In one species of *Elotherium*, not yet identified, a somewhat different proportion of these cuneiform facets is found; the mesocuneiform facet is larger and that for the entocuneiform smaller and in shape and in position more as in the recent pigs.

Kowalevsky's figures ('76, Taf. XXVII, Figs. 34, 37) do not display any characteristic differences in the structure of the navicular between the American and the European species of *Elotherium*. In *Anthracotherium* (Kowalevsky, '73, Taf. XI, Figs. 48, 59) the navicular has a long, massive and rugose hook, given off from the plantar side; the facet for the ectocuneiform is relatively smaller and that for the mesocuneiform much larger than in *Elotherium*, and the two surfaces are distinctly separated. Much the same description will apply to *Sus*. In *Hippopotamus* the navicular is very low and broad, and its distal facets are well distinguished.

The *entocuneiform* is in shape not unlike the rudimentary, nodular metapodials; it is high, narrow and compressed, thickest proximally and tapering distally to a blunt point. The navicular facet is relatively large, and is saddle-shaped, with curves the converse of those which occur on the corresponding surface of the navicular. Distally, there is a facet on the fibular side for the plantar projection from the head of the third metatarsal.

This element has not yet been found in connection with *Anthracotherium*, or with the European species of *Elotherium*. In *Sus* it is of quite a different form and decidedly smaller, while in *Hippopotamus* it is broader, heavier and shorter than in the fossil form.

The *mesocuneiform* is firmly ankylosed with the ectocuneiform, but its shape is, nevertheless, clearly distinguishable; it does not extend quite so far distally as the latter and is very small, especially transversely, and narrows toward the distal end. Its facet for the second metatarsal is obscurely displayed and it has no contact with the third. In *E. magnum* (Kowalevsky, Taf. XXVII, Figs. 35, 37) the two cuneiforms are even more completely fused than in the American species. In *Anthracotherium* the mesocuneiform is separate and has a large surface for articulation with the second metatarsal, as is also the case in *Hippopotamus*. In *Sus* this element is likewise distinct, but higher and narrower, and articulates with the second metatarsal more extensively than with the third.

The *ectocuneiform* is a large bone, of irregularly quadrate shape; its proximal surface bears a large, plane facet for the navicular, and the distal end is occupied by a still larger surface for the third metatarsal; the latter is abruptly contracted toward the plantar side. On the tibial side and distal to the mesocuneiform is a minute lateral facet for the second metatarsal. The contact with the cuboid is restricted to two facets near the proximal end, one dorsal and the other plantar, of which the latter is the smaller, but the more prominent. In *E. magnum* this bone is very much as in the American species, but the distal facet is of a different shape, not contracting so much toward the plantar

side (Kowalevsky, Taf. XXVII, Figs. 35). In *Anthracotherium* (Kowalevsky, '73, Taf. XI, Figs. 48, 59) the ectocuneiform is lower and has a more extended connection with the second metatarsal. The ectocuneiform of *Hippopotamus* is low, but very broad, in keeping with the great size of the third digit. In *Sus* this element is not so wide as in *Elotherium*, and differs from that of all the genera mentioned in having no contact with the second metatarsal, from which it is cut off by the articulation of the mesocuneiform with the third.

The *cuboid* is massive and large in all its dimensions, high, broad and thick. The proximal surface is about equally divided between the facet for the calcaneum and that for the astragalus, though the latter is slightly the wider. This facet, which is simply concave antero-posteriorly, is widest near the dorsal border, and in the middle of its course is deeply emarginated from the tibial side. The calcaneal facet is imperfectly divided into two parts, of which the dorsal portion is much the larger, particularly in width, while the plantar portion curves inward so as to lie, in part, behind the astragalar surface. The cuboid is firmly interlocked with the navicular by means of the deeply concave facet on the tibial side near the plantar margin, which receives the projection from the navicular already described. Dorsally the contact between these bones is limited to two small facets, one of which is proximal, and the other is distal on the navicular, median on the cuboid, where it helps to form the projection between the navicular and the ectocuneiform; this prominence is, however, very short. The facets for the ectocuneiform are also dorsal and plantar, and are just distal to those for the navicular. The distal end of the cuboid is taken up by the large facet for the fourth metatarsal, that for the rudimentary fifth being very small and lateral in position. The plantar hook is not long, but is very broad and massive, and bears on its tibial side a facet for the posterior projection from the head of the fourth metatarsal.

In *Elotherium magnum* (Kowalevsky, '76, Taf. XXVII, Figs. 34-36) the cuboid is not so high in proportion to its breadth as in the American species, and the tendinal sulcus on the fibular side is deeper. The cuboid of *Anthracotherium* is broader and lower and has, of course, a larger and more distal facet for the fifth metatarsal. In *Sus* similar proportions recur, and the division of the calcaneal surface into two parts is complete. In *Hippopotamus* the cuboid is very low and broad, and the astragalar facet is much wider than the calcaneal.

The *metatarsus*, like the metacarpus, consists of two functional (iii and iv) and two rudimentary members (ii and v).

Metatarsal II is a small nodule, which is much compressed laterally and tapers to a point at the distal end; the articulations are proximally with the mesocuneiform and laterally with the ectocuneiform and mt. iii.

Metatarsal III is considerably longer than the corresponding metacarpal and of a different shape, being much narrower transversely and thicker in the dorso-plantar diameter. The head is of moderate width, but the long and massive projection from the plantar side gives it great thickness. On the tibial side of the head is a depression in which lies the nodular mt. ii. The plantar projection bears a rounded, plane facet on each side; that on the tibial side is for the entocuneiform, and that on the fibular side is for mt. iv; a second facet for mt. iv is formed by a shallow depression near the dorsal border. The shaft of mt. iii is long, straight and slender; it is flattened on the plantar and fibular sides, rounded on the others. Toward the distal end the shaft gradually expands both in width and thickness; a very prominent and rough tubercle is developed on the fibular border of the dorsal face, just above the trochlea. The latter is rather low and narrow and has a prominent carina, which is confined altogether to the plantar face.

Metatarsal IV is a counterpart of mt. iii, with which it forms a symmetrical pair, though the plantar projection is even larger and heavier than that of the latter and articulates with the posterior hook of the cuboid. The connection with mt. iii is by means of two facets, the dorsal one a low, rounded prominence which fits into the depression on mt. iii already described, and the plantar one on the tibial side of the posterior projection. The two metatarsals are held very firmly together, externally by the hook of the cuboid and internally by the entocuneiform. A small depression on the fibular side of the head lodges the rudimentary mt. v. The shaft and distal trochlea are like those of mt. iii.

Metatarsal V is even more reduced than mt. ii. It has a thickened club-shaped head, which bears a facet for the cuboid and another for mt. iv, the two meeting at a very open angle. What remains of the shaft is slender and styliform. The mode of digital reduction in the pes, as in the manus, is entirely "inadaptive," the rudimentary mt. ii still clinging to the mesocuneiform and preventing mt. iii from reaching that tarsal, which is much diminished in size, while the ectocuneiform follows the enlargement of mt. iii.

Kowalevsky found no metatarsals associated with *E. magnum*. In *Anthracotherium* (Kowalevsky, '73, Taf. XI, Figs. 45, 55, 59) the lateral metatarsals are still large, functional and provided with phalanges; the median pair are relatively shorter and heavier than those of *Elotherium*, but in other respects resemble them closely. *Hippopotamus* has very short and massive metatarsals, which do not exceed the metacarpals in length and which retain the primitive mode of articulation with the tarsals. The metatarsals of *Sus* differ from those of *Elotherium* in much the same way as do the metacarpals of the two genera. The laterals are still functional, though much reduced, and the medians are short and very heavy, with the carinae completely encircling the distal trochleae; mt. iii has acquired an articulation with the mesocuneiform, cutting off mt. ii from the ectocuneiform.

The *phalanges* of the pes differ from those of the manus principally in their greater slenderness. The first phalanx is a little longer than that of the fore-foot, and decidedly more slender; the proximal trochlea is less deeply concave and the groove for the carina narrower and deeper. The second phalanx is of nearly the same length as in the fore-foot, but is much narrower and somewhat less asymmetrical in form. As Kowalevsky points out, the proportions of this phalanx are very exceptional among ungulates. The ungual is smaller in every dimension than that of the manus and, in particular, is narrower. Apparently, *Anthracotherium* (Kowalevsky, '73, Taf. XI, Figs. 52, 53) displays the same difference between the phalanges of the pes and those of the manus as does *Elotherium*. In *Sus* and *Hippopotamus* the phalanges of the two extremities differ very little.

Measurements.

Astragalus, length.....	0.083
Astragalus, width proximal trochlea.....	.045
Navicular, height.....	.024
Navicular, width.....	.029
Navicular, thickness.....	.044
Entocuneiform, height.....	.037
Entocuneiform width.....	.014
Mesocuneiform, height.....	.016
Ectocuneiform, height.....	.022
Ectocuneiform, width.....	.025
Cuboid, height.....	.045
Cuboid, width.....	.038
Cuboid, thickness.....	.047
Metatarsal iii, length.....	.181
Metatarsal iii, width proximal end.....	.029
Metatarsal iii, width distal end.....	.032
Metatarsal iii, thickness proximal end.....	.041
Metatarsal iv, length.....	.181
Metatarsal iv, width proximal end.....	.033
Metatarsal iv, width distal end.....	.031
Metatarsal iv, thickness proximal end.....	.046
Proximal phalanx, length.....	.060
Proximal phalanx, width proximal end.....	.032
Proximal phalanx, width distal end.....	.027
Second phalanx, length.....	.042
Second phalanx, width proximal end.....	.030
Second phalanx, width distal end.....	.024
Ungual phalanx, length.....	.032
Ungual phalanx, width proximal end.....	.022

X. RESTORATION OF ELOTHERIUM (Plate XVII).

The skeleton of this genus has a remarkable and even grotesque appearance. As in so many of the White River genera, the skull is disproportionately large, and the immense, dependant projections from the jugals, together with the knob-like protuberances on the mandible, produce a highly characteristic effect. The long, straight face, the prominent and completely enclosed orbits, the short cranium, the high sagittal crest, and the enormously expanded zygomatic arches give a certain suggestion of likeness to the skull of *Hippopotamus*. The neck is short, nearly straight and very massive, with prominently developed processes for muscular attachment. The trunk is short, but heavy; the anterior thoracic spines are very high and heavy, while those of the posterior region are short and quite slender. In consequence of the sudden shortening of the thoracic spines, a conspicuous hump is formed at the shoulders. The thorax is of moderate capacity and the loins are short. The tail appears to be of no great length, though the individual vertebræ are greatly elongated. The limbs are long and rather slender, and the fore and hind legs are of nearly equal height; the humerus and femur are almost the same in length, as are also the radius and tibia, while the pes is somewhat longer than the manus. The scapula is very large, especially in the vertical dimension, which considerably exceeds the length of the humerus, and has a short but prominent acromion; the pelvis, on the other hand, is rather small, the ilium having a long and slender peduncle, and only a moderate anterior expansion. The elongate limbs and slender, didactyl feet are in curious contrast to the huge head and short, massive trunk, and form a combination which would hardly have been expected.

Prof. Marsh has published, with a very brief explanatory text, a restoration of *Elotherium* ('94, Pl. IX) which differs in several details from the skeleton here figured. It is difficult to tell from the data furnished exactly how much of this restoration is conjectural, or to determine how far the discrepancies to be mentioned are the result of the association of parts of many different individuals in a single figure, and how far they are due to actual specific characters. On comparing the two figures, one is struck by the following differences: (1) In Marsh's restoration the skull is somewhat smaller in proportion to the length of the limbs. (2) The neck is more slender and the spines of the cervical vertebræ, notably those of the sixth and seventh, are much less developed. (3) The trunk is decidedly longer and twenty thoraco-lumbar vertebræ are figured. No reason is assigned for this departure from the well-nigh universal formula of the artiodactyls, which is nineteen, and we are therefore ignorant of the evidence by which it is supported. (4) The spines of the thoracic vertebræ are much more slender and decrease more gradually in length posteriorly, so that there is no such decided hump at the

withers. These spines are figured as having curious expansions at the tips, which are either absent or much less distinctly shown in the skeleton described in the present paper. (5) The lumbar region is longer and has neural spines which are lower and incline more strongly forward. (6) The conjectural restoration of the presternum is entirely different from the specimen herewith figured. (7) The scapula is relatively shorter and broader, and has a less prominent acromion. (8) The ilium has a shorter neck, expanding more gradually into the anterior plate and with the acetabular border of an entirely different shape. The ischium is much more slender, is more everted and depressed at the posterior end, and has a much less massive and prominent tuberosity.

Materials are yet lacking to determine how wide is the range of variation in the skeleton of the different species of *Elotherium*. So far as I have been able to observe, there are no important differences between the species, save those of size and proportions, the larger forms having more massive as well as longer bones. In particular, the great John Day species have exceedingly heavy limb and foot bones.

XI. THE RELATIONSHIPS OF ELOTHERIUM.

There has been a very general agreement, among those who have made a study of this genus, regarding the systematic position of *Elotherium*. The acute, compressed premolars have, however, led some observers to see affinities with the Carnivora and de Blainville went so far as to include the genus in his carnivorous family Subursi. Almost every other writer has referred these animals to the suillines. Leidy says of it: "*Elotherium* is a remarkable extinct genus of suilline pachyderms. . . . Its allies among extinct genera are *Chæropotamus*, *Palæochærus*, *Anthracotherium*, and among recent animals the Hog, Peccary and Hippopotamus" ('69, p. 174). Kowalevsky expresses the same idea in a more definite and specific way: "Schon bei dem ersten Anblick der Bezeichnung bleibt kein Zweifel über die Familie zu der diese Form gehört, nämlich den Suiden; sie bildet aber darin wegen des auffallenden Baues der didactylen Extremitäten eine sehr eigenthümliche Gattung. Plötzlich konnte eine derartige Form sich nicht bilden, das Entelodon hatte gewiss Vorahnen, deren Knochenbau einen allmäligen Uebergang von der tetradactylen zu der didactylen Form vermittelten, bis heute aber sind uns solche noch gänzlich unbekannt" ('76, p. 450). Zittel refers the genus to the *Achænodontinæ*, a subfamily of the *Suidæ* ('94, p. 335). Marsh erects a separate family for the genus, and says of it: "The *Elotheridæ* were evidently true suillines, but formed a collateral branch that became extinct in the Miocene. They doubtless branched off in early Eocene time from the main line which still survives in the existing swine of the old and new worlds" ('94, p. 408). Schlosser has expressed a somewhat different opinion

and has referred the genus to the bunodont division of the family *Anthracotheriidae*, which family he derives from an Eocene stock common to the *Anthracotheriidae*, the *Anoplotheriidae*, the *Hippopotamidae* and the *Suidae* ('87, p. 80).

The complete account of the dental and skeletal structure of *Elotherium* is now before us and yet it is hardly less difficult than before to determine its phylogenetic relationships and systematic position. The genus is so far specialized that it implies a long ancestry, not a member of which is, as yet, certainly known, although there are certain Eocene genera which throw some light upon the problem. In the absence of this ancestral series, we are without any sure criterion by which to distinguish parallelisms from characters of actual affinity, since only by tracing, step by step, all the gradations of a differentiating phylum, can we safely determine the true position of its members. However, some facts seem to bear a clear and definite significance. In the first place, it is plain that Marsh is right in forming a separate family for this genus, as it belongs to a line which diverged very early from the main stem, whatever that was. In the second place, the relationship of this family to the *Suidae* must be a very remote one. When we compare the skeleton of *Elotherium* with that of the swine and peccaries, point by point, the only notable resemblance between the two groups is found to consist in the bunodont character of the molar teeth, and this resemblance, standing by itself, cannot be regarded as at all decisive. The selenodont molar has been independently acquired by several distinct lines, and so far as the artiodactyls are concerned, the bunodont pattern is almost certainly the primitive one. That two widely separated families should each have retained a common primitive character is too frequent a phenomenon to excite surprise. In all other structures, skull, vertebral column, limbs and feet, no particularly close correspondences between the *Elotheriidae* and the *Suidae* can be detected, though that a common early Eocene progenitor should have given rise to both families is altogether likely.

Between *Elotherium* and *Hippopotamus*, on the other hand, are many points of resemblance. The likeness in the dentition is here quite as great or even greater than between either of these genera and the *Suidae*. In the skull there is much to suggest relationship, though combined with many striking differences, which may perhaps be referable to different habits of life, such as the enormous massiveness of the premaxillary and symphyseal region in the modern genus, the peculiar development of the canines and incisors and the elevated tubular orbits. In the skeleton the two genera are widely separated; *Elotherium* is a long-limbed, long-footed, didactyl creature, with small thorax and slender ribs, evidently of terrestrial habits. *Hippopotamus*, on the contrary, is a short-limbed, short-footed, tetradactyl and isodactyl form, with immense thorax and broad, almost slab-like ribs, which is chiefly aquatic in its habits. Whether the resem-

blances in skull and dentition indicate any relationship between the two families can be determined only when their history has been worked out. In any event, it is not probable that the relationship can prove to be closer than that both lines were derived from a common stock which separated from the other Artiodactyla at a very early date.

As has already been observed, no direct ancestors of *Elotherium* have yet been recovered, but there are certain Eocene forms which seem to be related to these unknown ancestors in such a way as to suggest the character of the latter. The *Achænodon* (*Elotherium*) *uintense* of Osborn ('95, p. 102) is such a form and differs from the *A. robustum* of the Bridger in the "great elongation of the face and the shortening of the cranium, both of which characters relate it to *Elotherium*" (*l. c.*, p. 103). This species is more specialized in several respects than the White River Elotheres, and like its forerunners of the Bridger, *A. robustum* and *A. insolens*, it has but three premolars in each jaw, and hence is not at all likely to be ancestral to the later genus. In the Wasatch *Achænodon* is represented by *A. (Parahyus) vagum* Marsh, which likewise has but three premolars, and, so far as it is known, differs from the Bridger species only in its smaller size. There is some reason to think, as Osborn has pointed out, that even *A. uintense* had four functional digits.

While it is very unlikely that *Achænodon* can have been the direct ancestor of *Elotherium*, there are, nevertheless, so many suggestive resemblances between the two genera, and the types of their dentition are so nearly identical, that we can feel little doubt as to their real phylogenetic relationship. In this case, *Achænodon* will represent a somewhat modified side-branch of the stem which culminated in *Elotherium*. A species of *Achænodon*, or of some closely allied genus, with unreduced dentition and unshortened face, may well prove to be the desired ancestral form. If so, the line had already become distinct in the Wasatch and the group thus has no subsequent connection with any existing artiodactyl family, unless possibly with the *Hippopotamidæ*. *Elotherium* would then represent the termination of an ancient and very peculiar line, which attained a remarkable degree of specialization in many parts of its structure and which extended its range over the whole Northern Hemisphere. At the same time, the cerebral development of the genus was very backward and this was doubtless one, at least, of the factors which led to its extinction. After the John Day, the line disappeared, leaving no successors.

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EXPLANATION OF THE PLATES.

Plate XVII.

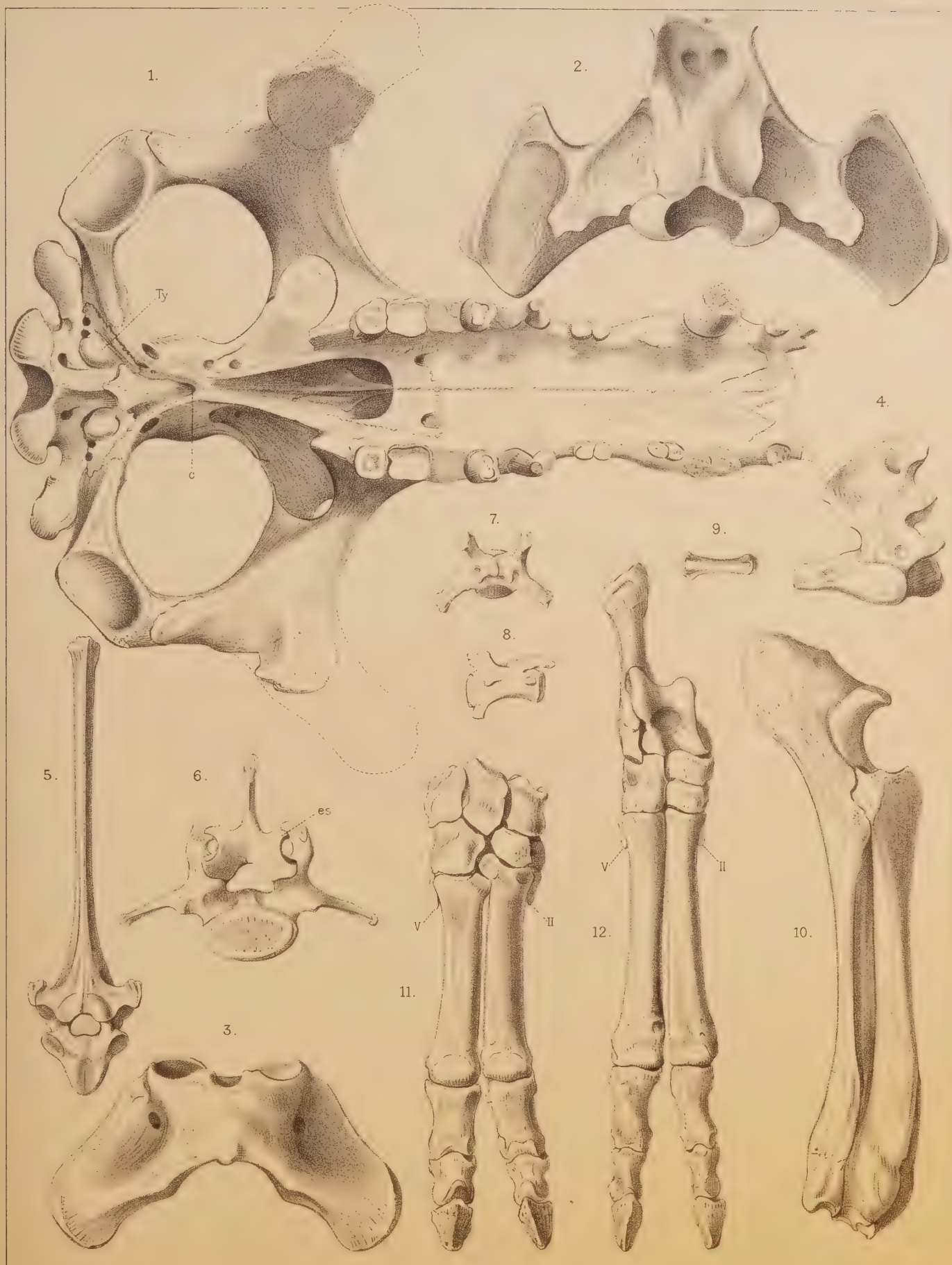
Skeleton of *Elotherium ingens* Leidy, from the Titanotherium beds of South Dakota, about $\frac{1}{11}$ natural size. Only the eighth thoracic vertebra and the distal ends of certain ribs are conjectural. The tail may well have been considerably longer, as only the vertebræ associated with the skeleton have been drawn.

Plate XVIII.

- Fig. 1. *Elotherium mortoni*. Basal view of skull, $\frac{1}{3}$ nat. size. *Ty*, tympanic bone; *c*, canal opening above and behind the posterior nares.
- Fig. 2. *Elotherium mortoni*. Occiput from behind, $\frac{1}{3}$ nat. size.
- Fig. 3. *Elotherium ingens*. Atlas, ventral side.
- Fig. 4. *Elotherium ingens*. Axis, left side.
- Fig. 5. *Elotherium ingens*. Fifth thoracic vertebra, from the front.
- Fig. 6. *Elotherium ingens*. Last lumbar vertebra, from behind. *es*, episphenial process.
- Fig. 7. *Elotherium ingens*. Anterior caudal vertebra, from above.
- Fig. 8. *Elotherium ingens*. (?) Fifth caudal vertebra, left side.
- Fig. 9. *Elotherium ingens*. Posterior caudal.
- Fig. 10. *Elotherium ingens*. Right ulna and radius.
- Fig. 11. *Elotherium ingens*. Right manus. ii, second metacarpal (conjectural); v, fifth metacarpal.
- Fig. 12. *Elotherium ingens*. Right pes. ii, v, second and fifth metatarsals.

(Figs. 3-12 are approximately $\frac{1}{4}$ nat. size and are of bones belonging to the skeleton figured in Plate XVII.)





ARTICLE VIII.

NOTES ON THE CANIDÆ OF THE WHITE RIVER OLIGOCENE.

BY W. B. SCOTT.

(INVESTIGATION MADE UNDER A GRANT FROM THE ELIZABETH THOMPSON FUND OF THE A. A. A. S.)

(Plates XIX and XX.)

Read before the American Philosophical Society, February 4, 1898.

The problems concerning the origin and mutual relationships of the various families into which the Carnivora Fissipedia are divided have not yet been satisfactorily solved, principally because of the rarity of well-preserved fossils representing the earlier and more primitive members of the families. Especially obscure are the questions dealing with the derivation and systematic position of the *Felidæ*, a family which by many authorities is regarded as occupying an entirely isolated position, not directly connected with any of the other groups. Hardly less puzzling, however, are many of the facts of canine phylogeny, such as the relations between the two great series of the wolves and the foxes, and the connection between the many divergent genera of successive geological horizons. No satisfactory answer to these questions can be given until many complete phylogenetic series of the Carnivora shall have been discovered, for so long as the numerous wide gaps which now separate the known members of the various series remain unbridged, those series must continue to be largely conjectural. At any time, new discoveries may call for an entire readjustment of our views regarding the lines of descent of the different families.

Recently, there has come into my hands some uncommonly well-preserved material for the phylogenetic history of the *Canidæ* and is the occasion of the present paper. This material was obtained for the museum of Princeton University by Messrs. Gidley and Wells, who in the summer of 1896 made a collecting trip through the Bad Lands of Nebraska and South Dakota. They had the good fortune to discover certain unworked localities where the exposures of the White River Oligocene proved to be richly fossiliferous and, in particular, yielded many unusually complete specimens of primitive dogs. A study of this material has brought to light some very remarkable and unexpected facts, which, to the writer at least, seem to require a revision of some current views upon the phylogeny of the carnivorous families, and to throw some light upon the obscure and difficult problems relating to the origin of the cats. The most valuable of these specimens are referable to

the genus *Daphænus* Leidy, which has long been known, though but very imperfectly, and several partially preserved skeletons permit an almost complete account of its osteology to be given.

DAPHÆNUS Leidy.

Proc. Acad. Nat. Sci. Phil., 1853, p. 393. *Amphicyon* Leidy (*non* Pomel), *ibid.* 1854, p. 157; *Ext. Mamm. Fauna Dak. and Nebr.*, 1869, pp. 32, 359; Cope, *Tertiary Vertebrata*, pp. 894, 896. *Canis* Cope, *Ann. Rep. U. S. Geolog. Surv. Terrs.*, 1873, p. 505.

This genus represents nearly the most primitive type of dogs which has so far been determined from the Tertiary deposits of North America. It was originally described and named by Leidy, who afterward mistakenly referred it to the European genus *Amphicyon*, a reference which was also adopted by Cope. Though more than forty years have thus elapsed since the first discovery of these animals, singularly little has been known about them, for the material obtained has been very scanty and very badly preserved. Fragments of jaws, a few very imperfect skulls and fewer limb-bones have hitherto been the only specimens found, in spite of long and careful search, and beyond the fact that *Daphænus* was apparently a primitive member of the canine phylum, little could be predicated of it.

The new material gathered by Messrs. Gidley and Wells fortunately removes this difficulty and gives us information regarding nearly all parts of the skeleton of these curious animals. These skeletal characters are of a very surprising nature and their interpretation is by no means easy. Especially remarkable are the many points of resemblance which we find between the structure of *Daphænus* and the corresponding parts of such primitive Machairodonts as *Dinictis*. Aside from the dentition and the shape of the mandible, these resemblances in structure between the primitive dogs and the early sabre-tooth cats are ubiquitous, and recur in the structure of the skull, of the vertebræ, of the limbs and of the feet. To bring out the full force of these remarkable characteristics, it will be necessary to enter into a detailed and somewhat tediously minute description of the osteology of *Daphænus*, so that the means of comparison may be completely laid before the reader.

I. THE DENTITION.

The dental formula of the genus is $I \frac{3}{3}$, $C \frac{1}{1}$, $P \frac{4}{4}$, $M \frac{3}{3}$, the same as that of *Amphicyon*, a resemblance which caused the erroneous identification of the two genera already referred to.

A. UPPER JAW (Pl. XIX, Fig. 2).—The incisors are closely crowded together and form a nearly straight transverse row; they are smaller and occupy less space both

transversely and antero-posteriorly than in most recent species of *Canis*. As in that genus, the external incisor is much the largest tooth of the series, and forms with the upper and lower canines a formidable lacerating apparatus. The diastema between the incisors and the canine is somewhat greater than in *Canis*, and the premaxillary is quite deeply constricted at that point, forming a groove for the reception of the lower canine.

The canine is of the usual compressed, oval section, but the compression is less decided than in *Canis*, the longitudinal diameter not so greatly exceeding the transverse. The fang of the canine is long and stout, producing a marked swelling upon the outer face of the maxillary; the crown is of only moderate length, but is both actually and proportionately heavier than in the coyote (*C. latrans*).

The premolars are notably small and simple; they increase in size regularly from the first to the fourth, the sectorial being, of course, much larger than any of the others. The first premolar is implanted by a single fang, and has a small crown of compressed conical shape, with much less conspicuous internal cingulum than in the recent species of the *Canidæ*. The second premolar is decidedly smaller than in most of the modern dogs, and is separated by longer interspaces from both the preceding and the succeeding tooth; it has a low, pointed, simple and much compressed crown, without the small posterior tubercles which are found in nearly all the recent species of the family. The third premolar is much longer and especially has a higher crown than p^2 , but has a similar shape, without posterior basal tubercles, and, like p^2 , is inserted by two fangs. The sectorial (p^4) is very primitive in character, as compared with that of the typical recent species of *Canis*. Certain modern members of the family, such as *Otocyon* and *Canis corsac*, for example, have, it is true, even smaller and simpler sectorials than *Daphænus*, but as in these forms this is doubtless due to a secondary simplification, they need not be drawn into comparison. The primitive character of the sectorial in the White River genus is shown in the thick, pyramidal shape of the antero-external cusp (*protocone*) which is less compressed and trenchant than in the modern species, in the smaller size of the postero-external cutting ridge (*tritocone*) and in the unreduced internal cusp (*deuterocone*) which is very much larger and more prominent than in *Canis*, and is carried upon a larger fang. The position of this inner cusp with reference to the protocone is the same as in the recent genus. As a whole, the sectorial is small and gives to the dentition a decidedly microdont character.

The premolar series of the two sides diverge quite rapidly posteriorly, each tooth, except p^1 , being oblique in position, with reference to the long axis of the skull, thus giving the bony palate its greatest width at the hinder edge of the sectorials. The obliquity of the teeth and their divergence posteriorly are even more strongly marked than in most recent dogs.

The upper molars are large and well developed, though the different species vary in this respect, *D. vetus* having larger tubercular molars than *D. hartshornianus*. The first molar is, in general, like that of *Canis*, but differs in certain details. Thus, the two external cusps are more conical in shape, more nearly equal in size, and are not placed so near to the outer edge of the crown, resembling in this respect the upper molars of certain creodonts, such as *Sinopa*; the large inner crescentic cusp is much as in *Canis*, though hardly so prominent, especially in *D. hartshornianus*; in *D. vetus* it is larger. The second molar is much like the first in shape and construction, but smaller and somewhat simplified, the conules being minute or altogether absent. The third molar is very small and has a low, transversely oval crown, in which separate elements are not distinguishable. This tooth is rarely preserved and none of the specimens at my disposal possess it, though the alveolus for it is almost always present; it is well figured by Leidy ('69, Pl. I, Fig. 5).

B. LOWER JAW (Pl. XIX, Figs. 5, 6, 7). In none of the available specimens are the lower incisors sufficiently well preserved to be worth description.

The canine is very much the same as in the recent members of the family. The premolars are somewhat more complex than those of the upper jaw. The first is very small and simple, while $p. \bar{2}$, $\bar{3}$ and $\bar{4}$, increase progressively in size and in the development of the posterior basal cusps. In the more ancient and primitive species ? *D. dodgei*, from the Titanotherium beds, the premolars are lower, thicker transversely and less acutely pointed, and have larger posterior basal cusps than in the later species from higher horizons. In all the species these teeth are more widely separated than in the modern genera.

The molars are very characteristic of the genus, but well-marked specific differences may be observed. In ? *D. dodgei* the anterior triangle of the lower sectorial is of only moderate height and the heel is but slightly concave, the outer and inner ridges (*hypo-* and *entoconids*) being very little raised. In *D. hartshornianus* the protoconid is high, narrow and pointed, and the talon is more concave than in the first-named species, and has more prominent internal and external cusps. In *D. vetus* the inner cusp of the talon (*entoconid*) is reduced and, as Cope has already pointed out ('84, p. 898), there is a tendency toward the formation of a talon with a single trenchant ridge, a tendency which is fully carried out in the genera *Temnocyon* and *Hypotemnodon* of the succeeding John Day horizon. In all the species of *Daphænus* the inferior sectorial is much more primitive than in the typical modern *Canidæ*, as is clearly shown by the higher and more conical protoconid, the lower and smaller paraconid and much less reduced metaconid. In fact, both the superior and inferior sectorials of *Daphænus* have a close resemblance to those of the creodont family *Miacidæ*, from which this genus could hardly be separated upon the ground of the dentition only.

The tubercular molars are not preserved in the specimens of ? *D. dodgei*; in *D. vetus* they are proportionately larger than in *D. hartshornianus*. M_2 is relatively large, especially in the antero-posterior diameter; it resembles the corresponding tooth of *Canis*, except for the presence of the small paraconid, thus giving to the tooth all the elements of a true sectorial, as is also the case in the creodont *Miacidæ*, though in the White River genus all the cusps are lower and more tubercular. M_3 is quite small, though both proportionately and actually larger than in species of *Canis* of similar stature, and is inserted by a single fang; the crown is of oval shape and has an irregularly ridged surface, without distinct cusps.

As a whole, the dentition of *Daphænus* is that of a primitive member of the *Canidæ* and resembles the dentition of the recent members of the family in general plan and structure.

Measurements.

	No. 11421.	No. 11424.	No. 10538.	No. 11423.	No. 11425.	No. 11422.
Upper dental series, length C to M 2.....	0.069		0.076			
“ incisors, transverse width .....	.014		.015			
“ canine, length .....	.010		.0115			
“ “ width.....	.008		.008			
“ P 1, length.....	.005	.005	.006			
“ P 2, “ .....	.008	.0085	.0095			
“ P 3, “ .....	.009		?.010	.009*		
“ P 4, “	?.014	.0145	.015	.015		
“ P 4, width.....	.0085	.009	.0105	.0105		
“ M 1, length.....	.012	.011	.011	.012		
“ M 1, width .....	.015	.015	.015	.016		
“ M 2, length.....	.0065	.007	.007	.007		
“ M 2, width.....	.010	.011	.011	.011		
Lower dental series, length C to M 3 .....	.078			.090*	.090	
“ premolar series, length .....	.036			.041*	.040	.0315
“ molar series, length .....	.026	.0245		.031*	.030	
“ canine, length.....	.011			.011*	.012	.010
“ “ width.....	.0085			.009*	.008	.007
“ P 1, length.....	.0045*			.005*	.004	.003
“ P 2, “ .....	.0085	.008		.009*	.010	.006
“ P 3, “ .....	.0095	.010		.010*	.011	.008
“ P 4, “ .....	.012	.012		.012*	.012	.011
“ M 1, “ .....	.014	.013		.014*	.017	.014
“ M 1, width.....	.007	.007			.009	.008
“ M 2, length .....	.0085	.008		.0095*	.0095*	
“ M 2, width.....	.006	.0055				
“ M 3, length.....	.003*	.004*		.006*	.004*	
“ M 3, width.....	.002*	.003*				

*Alveolus.

II. THE SKULL (Pl. XIX, Figs. 1-7).

The skull of *Daphænus* is exceedingly primitive in character and plainly shows many traces of the creodont ancestry of the genus. Unfortunately, well-preserved skulls are exceedingly rare and none of the species is represented by an altogether complete specimen. However, several more or less imperfect specimens have been recovered, which together give us information concerning nearly all parts of the skull.

As in the creodonts generally, the cranial region, reckoning from the anterior edge of the orbits backward, is exceedingly elongate, while the face in front of the orbits is very short, slender and tapering. The elongation of the cranium is not due to an enlargement of the cerebral fossa, which on the contrary is short, narrow and of relatively small capacity. The postorbital constriction, which marks the anterior boundary of the cerebral fossa, is notably deep and is removed much farther behind the orbits than in *Canis*. On the other hand, the cerebellar fossa is long, and the postglenoid processes occupy a more anterior position than in the existing species. In consequence of the elongate cranial region, the zygomatic arches are very long, as in the more primitive types of creodonts. The upper contour of the skull is nearly straight, the descent at the forehead being very slight and gradual, which gives to the skull an alopecoid rather than a thooid aspect. This resemblance is, however, entirely superficial, for the frontal sinuses are large and well developed, as in the thooid series of the modern *Canidæ*. The sagittal crest is low, but varies in the different species, being decidedly thicker and more prominent in the larger and heavier *D. vetus* than in the smaller and lighter *D. hartshornianus*.

Turning now to the more detailed study of the elements which make up the skull, we shall find a number of striking and significant differences from the existing representatives of the family, though the general aspect of the whole is distinctively canine.

The *basioccipital* is broad and quite elongate and has a much more decided median keel than *Canis*. All the occipital bones are firmly ankylosed in the specimens at my disposal; hence, in the absence of sutures, it will be necessary to describe the compound bone as a whole, without much reference to the elements of which it is made up. The occiput is of quite a different shape from that found in the existing members of the family, being broader, lower, and with a wide, gently arched dorsal border or crest (see Pl. XIX, Fig. 3); in *Canis* this crest is pointed and somewhat like a Gothic arch in shape. The occipital crest is thin, but much more prominent than in *Canis*, which is due to the larger and deeper depressions of the cranial walls behind the occipital lobes of the cerebral hemispheres, the shape of which is plainly visible externally. The foramen magnum has much the same low and broad outline as in *Canis*. The condyles are low, but well extended transversely, and on the ventral side they are sepa-

rated by a wider notch than in *Canis*. The depression, or fossa, external to the condyle is very much deeper and more conspicuous than in the modern genus, in consequence of which the condyles project more prominently backward from the occiput than in the modern dogs. The paroccipital processes are short, but quite stout and bluntly pointed; they project much more strongly backward and less downward than in the living forms, and are less compressed laterally. Another difference from the modern genus consists in the fact that, while in the latter the paroccipital process has quite an extensive sutural contact with the tympanic bulla, in *Daphænus* there is no such contact, the minute bulla being widely separated from the process. The direction taken by the paroccipital process in its course is thus evidently not determined by the size of the bulla, for in the John Day genera, *Temnocyon*, *Hypotemnodon* and *Cynodesmus*, in which the tympanic is greatly inflated, the shape and direction of the paroccipital are the same as in *Daphænus*, with its insignificant bulla. A considerable portion of the mastoid is exposed on the surface of the skull, but it is rather lateral than posterior in position, a difference from *Canis*, in which the mastoid is hardly visible when the skull is viewed from the side. The mastoid process is slightly larger than in the existing genus and is channeled on the inner side by a groove leading to the stylo-mastoid foramen.

The limits of the *basisphenoid* are not clearly shown in any of the specimens, but this element appears to have much the same broad and flattened form as in the recent dogs. The presphenoid is long and narrow and, as in the existing species, is almost concealed from view by the close approximation of the palatines and pterygoids along the median line. The ali- and orbito-sphenoids are not well displayed in any of the specimens, but so far as they are preserved, they differ little from those seen in the more modern members of the family.

The auditory bulla of *Daphænus* is very remarkable and differs from that of any other known carnivore. Its principal peculiarities were observed and noted by Leidy, but the material at his command was insufficient to enable him to describe these peculiarities with confidence. The *tympanic* is exceedingly small, and is but slightly inflated into an inconspicuous bulla, the anterior third of which is quite flat and narrows forward to a point. There is no tubular auditory meatus, the external opening into the bulla being a mere hole, but the anterior lip of this opening is drawn out into a short process, somewhat as in existing dogs. Behind the bulla is a large reniform vacuity or fossa, of which Leidy remarks: "At first, it appeared to me as if this fossa had been enclosed with an auditory bulla and what I have described as the latter was a peculiarly modified auditory process" ('69, p. 33). Several specimens representing both the White River and John Day species of *Daphænus* show that the fossa is normal and was either not enclosed in bone, or, what seems less probable, that the bony capsule was so loosely attached that it

invariably became separated from the skull on fossilization. At the bottom of the fossa (*i. e.*, when the skull is turned with its ventral surface upward) is seen the exposed periotic, or petrosal, which is only partially overlapped and concealed by the tympanic. Such an arrangement is far more primitive than that which is found in any other known member of the canine series, and is not easy to interpret. A clue to its meaning may, however, be found in the mode of development of the bulla in the recent *Canidæ*. Here, as is well-known, the structure consists of an anterior membranous and posterior cartilaginous portion, which eventually ossify and coalesce into a single bulla. Reasoning from this analogy, we may infer that in *Daphænus* the bulla was also composed of two portions, but that only the anterior chamber was ossified, the posterior one remaining cartilaginous. Communication between the two chambers was provided for by the space which separates the hinder edge of the anterior chamber from the petrosal. If this interpretation be correct, it supplies an interesting confirmation of the results derived from the ontogenetic study of the recent genera. At all events, it seems much more probable that we have to do here with a primitive rather than a degenerate structure.

The *parietals* are large and roof in most of the cerebral fossa; they are much less convex and strongly arched than in *Canis*, in correspondence with the smaller size of the cerebral hemispheres, and posteriorly the depressions behind the hemispheres are much larger and deeper. As already remarked, the sagittal crest varies in the different species, and is much thicker and more prominent in *D. vetus* than in *D. hartshornianus*. The frontals are more or less damaged in all the specimens and in none of those at my disposal is it possible to determine the posterior limits of these bones, though from the position of the postorbital constriction we may confidently infer that they formed a smaller proportion of the cranial roof than in the modern members of the family. The supraciliary ridges are feebly developed, especially in *D. hartshornianus*, and the postorbital processes are likewise much less prominent than in most of the recent dogs; from this process a ridge descends downward and backward to the optic foramen, which, though not prominent, is yet more so than in *Canis*. The frontal sinuses are large and yet in spite of them the forehead is nearly flat, both longitudinally and transversely, with a very shallow depression along the median line. The nasal processes of the frontals are long, narrow and pointed, and are separated by only a short interval from the ascending rami of the premaxillaries.

The *squamosal* is of moderate size and differs only in subordinate details from that of *Canis*. One such difference is the presence of a broad shelf-like projection, the posterior extension of the root of the zygomatic process, which overhangs the auditory meatus and is doubtless to be correlated with the lesser breadth and convexity of the brain. The glenoid cavity is like that of the recent species, but has a much more distinct internal boundary, due to an elevation of the squamosal at that point. The

zygomatic process is stout and well-developed, especially in *D. vetus*, which has heavier arches than a large wolf, while in *D. hartshornianus* the zygoma is lighter and more slender, much as in the coyote. The *jugal* is strongly curved upward, as well as outward, and is shaped quite as in *Canis*, forming nearly the whole anterior and inferior boundary of the orbit; the postorbital process is very feebly indicated, being even less prominent than in the modern genus, so that the orbit is more widely open behind. The *lachrymal* is rather larger than in *Canis*, forming more of the anterior orbital border, and has a quite well-developed spine.

The *nasals* have a general resemblance to those of *Canis*, but, in correspondence with the shortness of the whole facial region, they are considerably shorter, and somewhat broader and more convex transversely; their posterior ends are more simply rounded and have a less irregular suture with the frontals, while the anterior, free ends are much less deeply notched.

The *maxillary* is somewhat peculiar in shape, corresponding to the remarkably constricted; narrow muzzle. The facial portion of the bone is relatively higher than in existing representatives of the family, especially in front, its anterior border rising in a steeper and bolder curve. Just in advance of the orbits the maxillaries expand quite suddenly in the transverse direction, much more abruptly than in *Canis*. The infra-orbital foramen occupies nearly the same position, with reference to the teeth, as in the latter genus, being above the front edge of the sectorial, but it is very much nearer to the orbit, which occupies a more anterior position. The palatine processes of the maxillaries follow the shape of the muzzle, and are long, narrow for most of their length, but broadening much behind; anteriorly they are emarginated in an unusual degree to receive the long premaxillary spines.

The *premaxillaries*, especially their alveolar portion, are somewhat narrower than in *Canis*, and behind the external incisor the alveolar border is constricted on each side, forming well-marked grooves for the reception of the lower canines. The exposed part of the ascending ramus is much narrower than in the modern genus, forming a mere strip on the side of the narial opening. At the same time, this ascending ramus is relatively longer than in existing dogs and extends almost to the nasal process of the frontal. The anterior narial opening is somewhat larger proportionately than in the recent members of the family, especially in the vertical direction, and its borders are less inclined; the floor, formed by the dorsal surface of the horizontal rami of the premaxillæ, is more simply and deeply concave, and the horizontal rami themselves are less massive. The palatine processes of the premaxillaries are distinctly smaller than in *Canis*, while the spines are relatively longer and more slender. The incisive foramina are large and from them quite deep grooves are continued forward to the alveolar border, while in the modern genus these grooves are very shallow and feebly marked.

The *palatines* are shaped very much as in *Canis*. As a whole, the bony palate differs from that of the latter genus in the greater and more abrupt expansion of its posterior half, beginning at p^3 ; it is also somewhat more concave transversely and has a more prominent ridge along the median line. The palatine foramina are likewise somewhat different from those of recent dogs; one conspicuous opening on each side occupies the same position as in the latter, opposite the middle of the sectorial, but instead of a single opening opposite m^1 , is a group of two or three minute foramina.

The *Cranial Foramina*. Unfortunately, none of the specimens are sufficiently well preserved to permit a complete account of the cranial foramina, though the more important facts concerning these structures may be determined. Leidy states that in *D. vetus* "the anterior condyloid, Eustachian and oval foramina present very nearly the same condition as in the Wolf" ('69, p. 33). The specimen upon which Leidy's description was founded, belonging to the Academy of Natural Sciences of Philadelphia, has been mislaid and is not at present available for comparison, but the description cited above does not altogether apply to the cranium of *D. hartshornianus*, of which an account has been given in the foregoing pages. In this specimen the condylar foramen is widely removed from the condyle, much more so than in *Canis*, and is placed near the edge of the reniform fossa which lies behind the tympanic bulla. The existence of this fossa removes the necessity for a distinct foramen lacerum posterius, which is indicated only by a notch in the hinder margin of the fossa; similarly, the stylomastoid foramen is an open groove, only partially enclosed by bone. The postglenoid foramen is large and conspicuous and is not concealed by the anterior lip of the auditory meatus as is the case in the John Day *Cynodesmus*. The foramen lacerum medium appears to occupy a somewhat more internal position than in *Canis*, though this is not altogether certain, because of the unfavorable condition of the fossil just at this point. The Eustachian canal is more concealed under the long anterior process given off from the tympanic bulla than in the existing genus, and the foramen ovale is separated from the entrance to the canal by a much more prominent bony ridge, so that the foramen presents forward instead of downward.

By a curious coincidence all the crania of *Daphænus* in the Princeton museum are damaged in such a way that none of them displays the alisphenoid canal, the foramen rotundum or the foramen lacerum anterius, though there is no reason to doubt that all of these foramina were present and corresponded in position to those of *Canis*. The optic foramen is overhung by a ridge, already described, which is much more prominent than in the latter, and the lachrymal foramen is decidedly larger and more conspicuous. The parietal is perforated by a venous foramen which opens in the depression behind the cerebral hemispheres; this foramen, the postparietal, is not found in the modern genus.

The *mandible* differs considerably in the various species, though the comparison between them can as yet be but partially made, for the only specimen known to me in which the angle and coronoid process are preserved, is that figured by Leidy (*l. c.*, Pl. I, Fig. 2), which belongs to *D. vetus*. In ? *D. dodgei* (Pl. XIX, Figs. 6, 7.) the horizontal portion of the mandible is thick, heavy and relatively short; the inferior border is very far from straight, rising beneath the masseteric fossa almost to the level of the molars and descending forward from this point in a bold, sweeping curve, quite as in the modern *Canis aureus*; the masseteric fossa is very deep and its ventral border forms a prominent ridge, distinct from the lower border of the jaw; the symphysis is short and the chin abruptly rounded and steeply inclined.

In *D. vetus* the horizontal ramus is of an entirely different shape (see Pl. XIX, Fig. 5) being longer, more compressed and slender and with a decidedly straighter ventral border; the symphysis is longer and the chin more gently rounded, rising more gradually from the inferior margin of the ramus. The masseteric fossa is quite deeply impressed, though less so than in ? *D. dodgei*, and is very large, extending far up upon the ascending ramus. The angle is a stout hook, which is less elevated above the general level of the horizontal ramus than in modern wolves or foxes. The condyle also has a low position, below the level of the molars, while in recent species the condyle is raised above the molars, and in some species very much so. The ascending ramus has great antero-posterior extent, by which the condyle is removed far back of the last molar. This is a primitive feature which recurs in most creodonts and is evidently correlated with the characteristic elongation of the cranium and zygomatic arches. The coronoid process is high and wide, and has a bluntly rounded end; it inclines much more strongly backward than in *Canis* and has a much more concave posterior border. The condyle resembles that of the recent dogs, but is set upon a more distinct neck, is more extended transversely, and is less cylindrical in shape, tapering more toward the outer end.

In *D. hartshornianus* the mandible, so far as it is preserved in the various specimens, resembles that of *D. vetus*, save that the horizontal ramus is somewhat shallower and more slender.

The *Brain*. Very little can be said concerning the brain, since no complete cast of the cranial cavity is available for study. The general shape and development of the brain are, however, indicated in the specimen of *D. hartshornianus* already described (Pl. XIX, Fig. 1). Its proportions are very different from those found in existing members of the family, a difference which may be briefly stated as largely consisting in the much greater relative size of the cerebral hemispheres and smaller size of the olfactory lobes in the modern species. In *Daphænus* the brain is narrow and tapers rapidly toward the anterior end; the cerebellum and medulla oblongata are long, the

hemispheres narrow and short, and the olfactory lobes very large. The partially exposed cast of the cerebral fossa shows that the cerebral convolutions are fewer, simpler and straighter than in any known species of *Canis*, and are even more primitive than those of *Cynodesmus* (see Scott, '94, Pl. I, Fig. 2). The only sulcus visible in the specimen is apparently the suprasylvian, which is short and pursues a nearly straight course, but curving downward slightly at both ends. From the external character of the skull it is clear that the hemispheres overlap the cerebellum but little.

Measurements.

	No. 11421.	No. 11424.	No. 10538.	No. 11423.	No. 11425.	No. 11422.
Skull, length.....		?.151				
Cranium, length fr. occ. condyles to preorbital border		.108				
Face, length in front of orbits.....	.065	?.050	.073			
Zygomatic arch, length.....		.080				
Palate, length.....	.076		.092			
“ width at p ⁴.....	.044*	.047*	.052			
Mandible, length from chin to masseteric fossa.....	.084			.093	.096	?.679
“ depth at m ₁.....	.020	.018		.023	.025	.025
“ “ “ p ₁.....	.0175	.015		.017	.020	.019
“ thickness at m ₁.....	.010	.009		.010	.012	.012

* Approximate.

III. THE VERTEBRAL COLUMN.

The vertebral column is remarkable in many ways. All the regions of the column are well represented by several specimens of *D. vetus* and *D. hartshornianus*, but no complete backbone belonging to a single individual has as yet been recovered.

Cervical Vertebrae. The collection contains only a single imperfect specimen of the atlas and this belongs to *D. vetus*. Imperfect as it is, this atlas displays some important differences from that of *Canis* and most of these differences are approximations to the feline and viverrine types of structure. In *Daphænus* the atlas is elongate in the antero-posterior direction, the anterior cotyles are small and only moderately concave, and are somewhat more widely separated on the ventral side than in *Canis*. When viewed from above, the cotyles are seen not to project so far in front of the neural arch as in the cats, but farther than in the dogs. The posterior cotyles for the axis are small, nearly plane, and but slightly oblique in position, with reference to the fore-and-aft median line of the vertebra. These cotyles are more distinctly separated from the articular surface for the odontoid process of the axis than in the modern dogs, in which

all three facets are confluent. The neural arch is low and broad, considerably elongated from before backward, and without ridges of any kind, save an inconspicuous tubercle, which represents the neural spine. Near its anterior border the arch is perforated by the usual foramina for the first pair of spinal nerves. The inferior arch is very slender, forming a more curved bar and has a much less antero-posterior extension than in *Canis*.

Wortman ('94, p. 137) has pointed out that the foramina of the atlas display certain characteristic features in the various carnivorous families. "In all of the *Felidæ* which I have had the opportunity of studying, the [vertebrarterial] canal pierces the transverse process at its extreme posterior edge, where it is thickened and joins the body of the bone. The superior edge of this posterior border slightly overhangs the inferior edge. . . . This character appears to be very constant in the *Felidæ* and so far as we know the structure of the atlas in the more generalized *Nimravidæ* [Machairodonts], it is true of them also. In the *Canidæ*, upon the other hand, the foramen for the vertebral artery is situated well in advance of the posterior border of the process, and instead of having a fore-and-aft direction, as in the cats, pierces the process almost vertically from above. In the *Viverridæ* and *Hyænidæ* the position of the foramen is very much as in the cats. There is, however, an important difference between these two families and the felines where the artery enters the suboccipital foramen in the anterior part of the atlas. The difference consists in the formation of a bony bridge in this situation, which gives to the suboccipital foramen a double opening in the hyænas and civets, whereas it is single in the cats."

In *Daphænus*, it is interesting to observe, the foramina of the atlas are in all respects like those characteristic of the cats and thus depart in a very marked way from the arrangement found in the recent *Canidæ*. The transverse processes are broken away, so that their shape is not determinable, but enough remains to show that the atlanteo-diapophysial notch is not converted into a foramen, thus agreeing with the canines and felines and differing from most of the hyænas and civets.

The *axis* is likewise feline rather than canine in its general character and appearance. The centrum is elongate, narrow and depressed, with a thin and inconspicuous hypapophysial keel, running along the ventral surface, and has a slightly concave posterior face. The articular facets for the atlas are convex and rise higher upon the sides of the neural canal than in *Canis*, and on the ventral side they project below the level of the centrum, so that they are separated by a broad notch, which is not present in the modern dogs, and is not well marked in the cats. The odontoid process is a long, slender, bluntly pointed peg, with a heavy, rounded ridge upon its dorsal surface, which is continued back along the floor of the neural canal. The transverse processes are quite long and relatively very stout; they are shorter and heavier than in *Canis*, and keep more nearly

parallel with the centrum, not diverging so much posteriorly. As in the felines, the vertebrarterial canal is longer than in the modern dogs, and its posterior opening is not visible when the vertebra is seen from the side; the anterior opening is larger and is placed farther forward than in the recent *Canidæ*. The neural canal is proportionately larger than in the latter, both vertically and transversely, nor does it contract so much toward the hinder end. The neural spine forms the great, hatchet-shaped plate usual among the Carnivora, and in its details of structure it is feline rather than canine. In the latter group, the spine is not continued back of the postzygapophyses into a distinct process, but its hinder borders curve gently into them. In *Daphænus*, as in nearly all the cats and viverrines, the spine is drawn out into a blunt and thickened process behind the zygapophyses, from which it is separated by a deep notch. The zygapophyses are rather small and do not project so prominently from the sides of the neural arch as they do in *Canis*.

The other cervical vertebræ are more slender and lightly constructed than in the existing *Canidæ* of corresponding stature. The centra are long, narrow, depressed and very feebly keeled in the ventral median line; in most of the species this keel does not terminate in a posterior hypapophysial tubercle, such as is found in the existing dogs. In the largest species, however, *D. felinus*, the keels are more prominent, especially on the third and fourth vertebræ, and there is some indication of the tubercle. The centra are slightly opisthocœlous and the faces are somewhat oblique in position. In very few of the specimens are the transverse processes sufficiently well preserved to require description, and in such cases as they are present (as, for example, on the fifth and seventh cervicals of one individual of *D. hartshornianus*) they display no noteworthy differences from the corresponding processes of *Canis*. The vertebrarterial canal is, however, somewhat longer than in the latter.

The neural arches are very different from those seen in the modern representatives of the family. In them the dorsal surface of the neural arch is very broad and on each side projects outward as an overhanging ledge, which connects the prezygapophysis with the postzygapophysis of the same side; ridges and rugosities for muscular attachment are well marked and in the large species often very prominent; the zygapophyses, and especially the posterior pair, project but little in front of and behind the arches, and those of each pair are separated by notches of only moderate depth. In consequence of this arrangement, there are but small interspaces visible between the successive arches, when the vertebræ are in position. In *Daphænus*, on the other hand, the dorsal surface of the neural arch is relatively narrow, somewhat convex transversely and usually smooth, without ridges or tubercles; the overhanging ledge which gives such an appearance of breadth to the arch in *Canis* is little developed; the zygapophyses project far in advance of and

behind the arch, and between each transverse pair is a deep notch which greatly reduces the antero-posterior length of the bony arch in the median line. When the vertebræ are placed in position, the openings between the successive arches, on the dorsal side, are very large and are longer antero-posteriorly than broad transversely. In these peculiarities of the cervical vertebræ of *Daphænus* we find no approximation to the structure of the cats or the viverrines.

The neural spines are also quite differently developed from those of the recent dogs. The third cervical has no spine, merely a very faintly marked keel, the overhanging spine of the axis leaving no room for the development of one on the third vertebra. The fourth cervical has a very low spine, and on each successive vertebra the spine becomes higher and more pointed; that of the seventh is very high and slender, very much more prominent than in *Canis*, being almost as high, though not nearly so stout, as the spine of the first thoracic vertebra in the modern genus. The length of the spines in the neck constitutes another similarity to the structure of the felines.

Thoracic Vertebræ.—The number of trunk vertebræ characteristic of *Daphænus* cannot as yet be definitely determined for any of the species, for no specimen has been found with complete backbone. In one specimen of *D. vetus* are preserved twelve thoracic and five lumbar vertebræ and the type of *D. felinus* contains six lumbars. It is altogether probable that the extinct genus agreed with the existing dogs in having thirteen thoracics and seven lumbars. The first thoracic has a broad, very much depressed centrum, with anterior face convex and posterior face deeply concave. The prezygapophyses project forward very strongly and, as in the cervicals, the notch between them is very deeply incised, invading the base of the spine, a very different arrangement from that seen in *Canis*; these processes are relatively larger and more concave in *D. vetus* than in *D. hartshornianus*. The postzygapophyses are much smaller, but project prominently from the hinder end of the neural arch, extending both laterally and posteriorly; the articular faces are somewhat convex transversely and have an oblique position, presenting outward rather more than downward. The neural spine is high and compressed, shaped very much as in *Canis*, but somewhat more slender. The transverse processes are very long, prominent and heavy, especially in the large species, *D. felinus*; at the distal end of the process is a large and deeply concave facet for the tubercle of the first rib.

The second thoracic very much resembles the first, but has a smaller, narrower, lighter, and much less depressed centrum; the prezygapophyses are smaller, less concave and less widely separated, while the postzygapophyses are larger and present downward, instead of obliquely outward, as they do on the first. The transverse processes are much smaller in every dimension than those of the first thoracic, and spring from the neural

arch at a higher level, though they are still very prominent and carry large, concave facets for the second pair of ribs. The neural spine is somewhat heavier than on the preceding vertebra, and was probably higher, as well, but in none of the specimens is the spine preserved for its entire length.

The other vertebræ in the anterior part of the thoracic region have rather small centra, and in general character are very much like those of *Canis*. The (?) sixth vertebra has a curiously shaped spine, which exaggerates the condition seen in the modern genus; its proximal portion is inclined very strongly backward, while the distal portion is curved so as to project upward; the other thoracics, as far back as the (?) tenth, have similar spines. One very marked difference from the recent *Canidæ* consists in the deep notch which, in *Daphænus*, separates the two prezygapophyses. The anticlinal vertebra is probably, as in the existing dogs, the tenth, and at this point the thoracic vertebræ undergo an abrupt change of character, assuming more the appearance of lumbar. In *Canis* the spine of the tenth thoracic is exceedingly small and much lower than those of the ninth and eleventh, but in *Daphænus*, on the other hand, the spine is much better developed, both in length and thickness; the postzygapophyses are small, somewhat convex and placed high up upon the neural arch, presenting outward. The (?) eleventh thoracic is not preserved in any of the specimens. The (?) twelfth and thirteenth are much like lumbar, except for the smaller and lower spines, thickened at the distal end, and for the entire absence of transverse processes, which in *Canis* are present, though very short, even on the thirteenth; the anapophyses are remarkably long and stout, being much heavier and more prominent than in the recent dogs, and high, massive metapophyses rise above the prezygapophyses.

The *lumbar vertebræ* (Pl. XIX, Fig. 8) were probably seven in number, though not more than six have been found in connection with any one specimen. These vertebræ are remarkable for their relatively great size and massiveness, and for the length of all their processes, being in these respects feline, rather than canine in character and appearance. Assuming that seven is the full number, the missing one will then be the third, and the following description is made upon that assumption. The centra increase in length posteriorly, reaching a maximum in the fifth and sixth, but the seventh is no longer than the first, though much broader and heavier. Compared with those of *Canis*, these centra are longer, stouter, less depressed and more rounded. The transverse processes are longer and heavier than in *Canis* and less so than in the large species of *Felis*. The neural spines are likewise intermediate in character between those of the recent dogs and of the larger felines; they are much higher, more extended antero-posteriorly, more thickened at the distal end and more steeply inclined forward, than in the former. In *D. felinus* especially, the great height of these spines is very striking and the resemblance

of the lumbar vertebræ to those of the contemporary Machairodont *Dinictis* is very great. Another similarity in the structure of the lumbar vertebræ between *Daphænus* and the felines consists in the great height and heaviness of the metapophyses, which are much better developed than in the recent *Canidæ*; on the last lumbar these processes become very much reduced and are, in fact, almost rudimentary. The anapophyses are smaller than on the thoracic vertebræ and diminish in size on each successive vertebra posteriorly; only on the first and second are they very large and prominent. In the existing representatives of the *Canidæ* these processes are rudimentary, except on the first lumbar, where they are small. This constitutes another point of resemblance between *Daphænus* and the cats, and emphasizes the statement already made, that the posterior thoracic and lumbar vertebræ of this Oligocene dog, for as such it must be regarded, are decidedly more feline than canine in appearance, using those terms only with reference to their modern application.

The *sacrum* (Pl. XX, Fig. 14) consists of three vertebræ, and, in correspondence with the great development of the tail, it resembles that of the larger cats in many respects. Only the first sacral vertebra has any contact with the ilium and bears massive pleurapophyses. The centra are much larger and heavier than in the modern dogs and the postzygapophyses much more prominent. The resemblance between the sacrum of *Daphænus* and that of the large cats is not very close, and the following differences may be noted: (1) the neural spines are much lower and weaker; (2) the neural canal is smaller; (3) the transverse processes of the second, and especially of the third vertebra, are decidedly shorter, so that the posterior portion of the sacrum appears much narrower. From the sacrum of the recent dogs that of *Daphænus* differs particularly in its greater proportionate length and massiveness.

Caudal Vertebræ (Pl. XIX, Figs. 9, 10).—In none of the specimens of the collection is the tail completely preserved, the largest number of vertebræ found being thirteen of one individual and eleven of another, but enough remains to satisfactorily demonstrate its character. The tail is remarkably long and stout and is, in fact, almost as well developed as in the leopard or tiger, and, consequently, is much longer and thicker than in any of the existing *Canidæ*.

The first caudal vertebra is quite like that of the lion, but is relatively lighter and more slender in all its parts, and has a short but distinct neural spine; the zygapophyses are very prominent, and even the metapophyses are distinctly shown; the transverse processes are very long, but are not so broad proportionately as in the lion, and are quite strongly recurved. Posteriorly the caudal vertebræ become successively more and more slender and elongate, while all of the processes are gradually reduced in size. The middle region of the tail is made up of extraordinarily elongate vertebræ,

which are very much like the corresponding caudals of the long-tailed cats, but are decidedly longer and more slender proportionately. Near the tip of the tail the vertebræ become very small.

The *ribs* are represented only by fragments, which, so far as they are preserved, do not differ materially from those of the modern *Canidæ*. From the character of the posterior thoracic vertebræ, it may be inferred that the eleventh, twelfth and thirteenth pairs of ribs did not possess tubercles.

Of the *sternum* very little is preserved. One segment of the mesosternum is associated with the type specimen of *D. felinus*; it has much the same shape as in modern dogs, but is somewhat thicker transversely and shallower vertically, in proportion to its length. Another segment accompanies a specimen of *D. vetus* (No. 11424) and is much wider and more depressed than in any of the existing fissipedes, except certain hyænas. As the association of this weathered fragment with the skeleton of *Daphænus* may be accidental, no great stress can be laid upon it.

Measurements.

	No. 11421.	No. 11423.	No. 11425.
Atlas, length		0.031	
Axis, length (excl. of odontoid) .....			.041
“ “ of odontoid process .....		.013	.014
“ width anterior face .....		.028	.031
Third cervical vertebra, length .....		.030	.031
“ “ “ width of anterior face .....		.014	.016
Fourth “ “ length .....		.030	.030
Fifth “ “ “ .....		.030	
Sixth “ “ “ .....	.024	.028	.031
“ “ “ width of anterior face .....	.012	.014	.016
Seventh “ “ length .....	.022	.024	.026
First thoracic vertebra, length .....	.017	.020	.021
Thirteenth thoracic vertebra, length .....	.021	.024	.024
“ “ “ width anterior face .....	.017	.021	.021
First lumbar vertebra, length .....		.028	.028
“ “ “ width anterior face .....		.020	.020
Sixth “ “ length .....		.037	.037
“ “ “ width anterior face .....		.021	.021
Last lumbar, length .....		.030	.028
“ “ “ width anterior face .....		.022	.025
Sacrum, length .....		.058	
“ width across pleurapophyses .....		.051	.051
First caudal vertebra, length .....		.020	
“ “ width across transverse processes .....		.060	
Median caudal, length .....		.040	

IV. THE FORE LIMB.

Of the *scapula* no part has yet been recovered.

The *humerus* (Pl. XX, Fig. 15) differs in several important respects from that of the recent *Canidæ*. Unfortunately, in all of the specimens the proximal end of the bone is broken away, so that nothing can be determined with regard to the head, tuberosities, or bicipital groove. The shaft is rather short and stout, and is arched strongly forward, though less so than in *Canis*; the deltoid ridge descends low upon the shaft and is very prominent, much more so than in the existing canines or felines, though it does not attain the exaggerated development seen in the early *Machairodonts*, such as *Dinictis* and *Hoplophoneus*. The distal end of the humerus is remarkably cat-like in appearance, and does not suggest any relationship with the modern *Canidæ*. The supinator ridge is very prominent and extends far up upon the shaft, while in *Canis* this ridge is almost obsolete. The internal epicondyle is very much larger, more rugose and more prominent than in the modern genus, quite as much so, indeed, as in the cats, and there is a large entepicondylar foramen, bridged over by a stout, straight bar of bone. The anconeal fossa is lower, broader, shallower, and altogether more cat-like than in *Canis*, and does not perforate the shaft to form a supratrochlear foramen. The humeral trochlea is extremely low, its vertical diameter being conspicuously less than in *Canis* and less even than in *Felis*, resembling in this respect the humerus of the sabre-tooth *Hoplophoneus*. The shape of the trochlea is of feline appearance, having a simply convex surface for the capitellum of the radius, and no such distinctly marked intercondylar ridge or convexity as is found in the recent *Canidæ*. The internal border of the trochlea is prolonged downward into a large flange.

The *radius* (Pl. XX, Fig. 16) is also singularly cat-like in structure and in all its parts is much more feline than canine. The proximal end bears an oval and somewhat concave capitellum, for articulation with the humerus; its transverse diameter only slightly exceeds the antero-posterior dimension. The anterior notch of the humeral surface is somewhat more deeply incised than in *Felis*, but not more so than in *Hoplophoneus*, which has an entirely similar capitellum. The articular facet for the ulna surrounds more than half the circumference of the head of the radius, which is in remarkable contrast to the small size of this facet in *Canis*. The shape and mode of articulation of the bones which enter into the formation of the elbow-joint show that *Daphænus* possessed unimpaired powers of pronation and supination of the manus. In the existing members of the *Canidæ*, on the contrary, this power is lost, the head of the radius being so much expanded transversely, as to occupy nearly the whole width of the humeral trochlea, and interlocking with it in such a way as to allow only the movements of flexion and extension.

The shaft of the radius in *Daphænus* is slender and has a similar shape to that which we find in the cats, although it is not so much expanded distally; it is thus very different from the broad, antero-posteriorly compressed and almost uniform radial shaft of the modern dogs. The distal portion of the radius is likewise very feline in appearance, but is rather lighter and narrower in proportion to the length of the bone; it is convex anteriorly and quite deeply concave posteriorly, with well-marked sulci for the extensor tendons upon the dorsal face. The distal facet for the ulna is small and of sub-circular shape and forms quite a projection upon the ulnar side; upon the inner side of the distal end is a tubercle, which is even more rugose and prominent than in *Felis*, and more distinctly set off from the carpal surface. This carpal facet has a shape like that seen in the cats, and is more concave transversely and narrower in the dorso-palmar diameter than in the existing forms of *Canidæ*, and its internal border is more prolonged distally into a downward projecting flange.

Had this radius been found isolated, one would hardly have hesitated to refer it to one of the Machairodont genera, so completely does it differ from the radius of the modern dogs. Fortunately, there is no room for scepticism regarding the reference of this bone to *Daphænus*, for several of the specimens, representing different species, have radii of the same type. In this connection, it may be of interest to note that the Eocene creodont genus, *Miacis*, which has a remarkably canine type of dentition, has a very cat-like form of radius.

The *ulna* is hardly less characteristically feline than the radius. In marked contrast to the creodonts, which have a very long olecranon, that of *Daphænus* is rather short; its antero-posterior diameter is proportionately less than in *Felis*, or even than in *Canis*, and its postero-superior angle is thickened and rugose, though somewhat less so than in either of the modern genera mentioned, which gives its proximal border a straighter contour than in them. The tendinal sulcus is wider and deeper than in the recent dogs, less so than in the cats. The sigmoid notch is deeply incised, but describes a parabolic curve rather than a semicircle; the proximal humeral facet is relatively much wider than in *Canis*, and is continuous with the broad distal internal facet, which is likewise broader than in the existing dogs and is shaped much as in the cats, while the external distal facet is nearly or quite obsolete. The radial facet is large, quite deeply concave, and continuous or single, while in *Canis* it is much smaller and is divided by a sulcus into two portions.

The shaft of the ulna is stout and, in the proximal portion, laterally compressed, tapering toward the distal end, where it becomes trihedral in section. In shape this shaft is very much like that of the cats and differs entirely from the ulnar shaft of the recent *Canidæ*, which has become very much more slender, reduced and styliiform, a

change which is obviously correlated with the increased size of the radius. The distal end of the ulna in *Daphænus* is narrow and carries a continuous convex articular surface, which is not divided into separate facets for the pisiform and pyramidal. The distal radial facet is raised upon a prominent projection, another point of resemblance to the cats and of difference from the existing representatives of the *Canidæ*.

Measurements.

	No. 11424.	No. 11425.
Humerus, width of distal end.....		0.050
“ “ “ trochlea.....		.033
Radius, ant.-post. diameter of head.....		.016
“ transverse “ “ “ .....		.021
“ breadth of distal end.....	.022	
“ “ “ carpal facet.....	.014	
Ulna, “ “ distal end.....	.013	
“ “ “ carpal facet.....	.008	

V. THE MANUS.

Of the *carpus* the only element preserved is a single scapho-lunar of *D. vetus*, interesting as showing that the coalescence of these elements had already taken place. This bone differs in a marked way from that of both recent canines and felines, but resembles the scapho-lunar of the White River sabre-tooth, *Hoplophoneus*. It is broad transversely and thick in the dorso-palmar diameter, but very low proximo-distally, even more so than in *Canis*; the tubercle at the postero-internal angle of the bone is well marked, but smaller than in the felines or modern dogs. The radial facet is simply convex in both directions, not having the postero-internal saddle-shaped extension which occurs in the recent dogs. This radial facet is reflected far over upon the dorsal and internal surfaces of the bone, converting the inner side into a thin edge, formed by the junction of the radial and trapezial facets.

On the distal end of the scapho-lunar are three plainly distinguished facets, for the unciform, magnum and trapezoid respectively. The very deeply excavated unciform surface reduces the ulnar side of the scapho-lunar to an edge, not very much thicker than the radial border, and hence there is no well-defined facet for the pyramidal, such as occurs in *Canis*. The shape and proportions of the unciform and magnum surfaces are very much as in the latter genus, but that for the trapezoid is not demarcated from that for the trapezium, though there can be little doubt that the latter element articulated with the scaphoid, as it certainly does both in *Cynodictis* and in *Canis*. The general

shape of the scapho-lunar, recalling that which we find among the mustelines, strongly suggests that *Daphænus* had a plantigrade or, at least, a semiplantigrade gait.

The *metacarpus* (Pl. XX, Fig. 17) consists of five members, which bear little resemblance to those of the recent *Canidæ*. Schlosser ('88, p. 24) has pointed out the essential characteristics of the metacarpus among the modern forms, and it will be well to quote his description, in order to make clear how widely *Daphænus* departs from the arrangement which has been attained by the later representatives of the family.

“Die Metapodien haben sich auffallend gestreckt und sind zugleich kantig geworden. Sie zeigen nahezu quadratischen Querschnitt, in Folge ihres gegenseitigen Druckes; sie liegen einander nämlich ungemein dicht an. . . . Die distalen Gelenkflächen haben das Aussehen von sehr kurzen Walzen und sind beiderseits scharf abgestutzt. Es lässt sich eine freilich sehr entfernte Aehnlichkeit mit dem Fusse von Hufthieren, namentlich vom Schweine—nicht verkennen. . . . Die Anordnung der Carpalien ist scheinbar primitiver als bei den übrigen Raubthieren, wenigstens als dieselben unter einander und mit den Metacarpalien nur reihenweise artikuliren, statt wechselseitig in einander zu greifen. Auch hat nur das Scapholunare eine etwas beträchtlichere Grösse erreicht, Magnum sowie Trapezoid und Trapezium bleiben sehr kurz und enden sowohl oben als auch unten sämmtlich in einer Ebene. Demzufolge liegen auch die proximalen Facetten der Metacarpalien so ziemlich in einer einzigen Ebene.”

This description of the structure of the manus in the recent *Canidæ* does not at all apply to *Daphænus*. In this genus the metacarpals are remarkably short and quite slender; they are not very closely approximated, but diverge somewhat toward the distal end, and hence they have not acquired the quadrate shape which Schlosser mentions as so characteristic of the modern dogs. The general appearance and character of the metacarpals, and their mode of articulation with each other and with the carpals are very much as in the wolverine (*Gulo*).

The *first metacarpal*, even of the large *D. felinus*, is actually not much longer than that of the coyote (*C. latrans*), but is much longer in proportion to the other metacarpals, as well as much stouter and in every way better developed. The proximal end is thickened both transversely and antero-posteriorly, and bears a large facet for the trapezium, which must have been a relatively large bone; this facet is convex in the dorso-palmar direction and is very slightly concave transversely, while in *Canis* it is deeply concave in this direction. In *D. vetus* the articular surface for the trapezium is more oblique and inclined toward the radial side than in *D. felinus*. There is no other well-defined facet for any carpal but the trapezium, nor for mc. ii. The shaft is short, slender, of oval or subcircular section, and arched toward the dorsal side.

The distal end is large and has a well-developed trochlea, which is much more strongly convex than in *Canis* and of a different shape, the modern genus having here a trochlea which is more like that of a phalanx than of a typical metacarpal. In *Daphænus*, but not in *Canis*, there is a well-defined palmar carina, and the lateral processes for ligamentous attachment are more prominent than in the recent type.

The *second metacarpal* is much longer and stouter than the first, though very short with reference to the size of the animal and to the length of the other segments of the fore limb. The proximal end is not much expanded transversely, but has a great dorso-palmar extension, the head projecting much farther behind the plane of the shaft than in *Canis*. The facet for the trapezoid is less concave transversely than in the modern genus and is of more uniform width, narrowing less toward the palmar side; the ulnar border rises more above the head of mc. iii and has a more extensive contact with the magnum. Though larger than in the recent *Canidæ*, this contact with the magnum is much smaller than in existing felines, and is of about the same proportions as in the early sabre-tooth, *Hoplophoneus*. The combined facets for the magnum and for mc. iii form a broad, curved band upon the ulnar side of the head, which is made slightly concave to receive the adjoining metacarpal. No distinctly marked facet for the trapezium is visible upon the radial side. The shaft is short, weak, of transversely oval section, and is arched toward the dorsal side. The distal end is expanded, and made broad by the large, rugose processes for the attachment of the lateral metacarpo-phalangeal ligaments, processes which are much better developed than in *Canis*. The distal trochlea is of a quite different shape from that seen in the modern genus, being narrower, higher and of more nearly spherical outline, and is demarcated from the shaft by a deep depression, such as does not occur in the existing members of the *Canidæ*. The palmar carina is prominent and thins to a narrow edge.

The *third metacarpal* is incomplete in the only manus found in the collection (*D. felinus*, No. 11425, Pl. XX, Fig. 17) as it lacks the distal end. The portion preserved is, however, as long as the whole of mc. ii and the complete bone was evidently considerably longer. The shape of the proximal end is much as in *Canis*, except for the relatively greater dorso-palmar diameter. The magnum facet is narrow, but deep, somewhat concave transversely and strongly convex antero-posteriorly, but less so than in existing dogs. The facet on the radial side for mc. ii is larger, more oblique and more prominent, and is more extensively overlapped by mc. ii than in the latter, and the surface for mc. iv, while not so deeply concave, is larger. When the third and fourth metacarpals are placed together in their natural positions, it is seen that the former rises higher proximally than the latter and has a contact with the radial side of the unciform, which, though narrow, is larger than in *Canis*. The shaft is somewhat more slender than

that of mc. ii and is of a more quadrate section, the dorsal and lateral surfaces forming distinct angles.

The *fourth metacarpal* has a narrow, but deep head, which projects prominently behind the plane of the shaft; the facet for the unciform is slightly concave in the transverse and strongly convex in the dorso-palmar direction. Compared with the corresponding bone of *Canis*, the following differences in the shape of the facets for the adjoining metacarpals may be observed. The surface for mc. iii is, as in the recent animals, divided into dorsal and palmar portions, but they are not completely separated; the dorsal moiety is much larger, but not nearly so prominent, and the palmar portion is much smaller. The facet for mc. v is of about the same shape in both genera. The shaft is slender and nearly straight, but slightly arched toward the dorsal side; though relatively short, it considerably exceeds mc. ii in length. The prominence of the lateral ligamentous processes gives great proportionate breadth to the distal end. The trochlea is like that of mc. ii, except for its greater size and presents the same differences from the modern type.

The *fifth metacarpal* has been lost from the specimen.

The *phalanges* are very remarkable, but can be most conveniently described in connection with the pes, with which the most complete specimens are associated.

Measurements.

	No. 11424.	No. 11425.
Scapho-lunar, breadth.....	0.015	
“ “ depth (dorso-palmar).....	.011	
Metacarpal i, length.....	.023	.026
“ breadth of proximal end.....	.007	.009
“ “ distal end.....	.006	
“ “ distal trochlea.....	.0045	
Metacarpal ii, length.....		.0395
“ “ breadth of proximal end.....		.009
“ “ “ distal end.....		.012
“ “ “ trochlea.....		.009
Metacarpal iii, breadth of proximal end.....		.0105
Metacarpal iv, length.....		.050
“ “ breadth of proximal end.....		.0095
“ “ “ distal end.....		.012
“ “ “ “ trochlea.....		.010

VI. THE HIND LIMB.

The *pelvis* is represented by several specimens belonging to *D. vetus*, *D. hartshornianus* and *D. felinus*, all of them incomplete, but so supplementing one another, that the shape of the os innominatum may be determined, with the exception of the anterior border of the ilium, which is unfortunately missing from all the individuals.

So far as it is preserved, the pelvis is rather feline than canine in character, both in its general outlines and in its details of structure. The neck or peduncle of the ilium is wider and shorter than in *Canis*, narrower than in *Felis*; the anterior plate expands to its full width somewhat more abruptly than in the latter, but enough of the broken fossils remains to show that the iliac plate has the narrow form which is found in the cats and does not expand so much at the free end as in the modern dogs. The gluteal surface is not simply concave, as it is in the two recent genera mentioned, but is divided into two unequal fossæ by a prominent longitudinal ridge, such as occurs, though not so prominently developed, in certain viverrines. This feature is repeated in another White River dog, *Cynodictis*, and is almost duplicated in the contemporary sabre-tooth, *Dinictis*, another of the many correspondences between *Daphænus* and the early Machairodonts. The sacral surface is placed much less in advance of the acetabulum than in *Canis*, and occupies about the same relative position as in the cats. The ischial border of the ilium is, for most of its length, nearly straight and parallel to the acetabular border, but descends more abruptly than in either the recent dogs or cats, and follows a course more like that seen in *Viverra*. As in *Canis*, the acetabular border is more distinctly defined than in the true felines, and ends near the acetabulum in a long, roughened prominence, the anterior inferior spine. The pubic border is very short, and hence the iliac surface is not well defined. The acetabulum is of moderate size and has somewhat more elevated borders than in the cats.

The ischium, which in the existing *Canidæ* is much shorter than the ilium, is very elongate, and is proportionately even longer than in the felines. The anterior portion of this element is straight, rather slender, and of obscurely trihedral section; behind the acetabulum the dorsal border is arched upward into a convexity, the spine of the ischium, terminated abruptly behind by the ischiadic notch, which is as conspicuous as in the cats, while in *Canis* it is very faintly marked. The posterior part of the ischium is expanded into a broad and massive plate, which is very rugose upon the external surface. This posterior portion is not so strongly everted and depressed as in the modern dogs, and there is no such stout and prominent tuberosity, which, again, constitutes a resemblance to the cats.

The pubis is L-shaped and its anterior, descending limb is unusually long, broad and thin, much more so than in the felines or modern dogs. The obturator foramen is

very large, forming an oval, with its long axis directed antero-posteriorly, in shape and size agreeing much more closely with the condition found in the cats than with that of the recent dogs.

The *femur* (Pl. XX, Fig. 18) is stout, and long in proportion to the length of the fore-limb bones, but not very long as compared with the size of the animal. While not differing in any very marked fashion from the thigh-bone of *Canis*, it yet has some resemblances to that of the felines. The small, hemispherical head is set upon a longer neck than in recent dogs and has a smaller, deeper and more circular pit for the round ligament, than in the latter. As in *Canis*, the head projects more obliquely upward and less directly inward than in *Felis*. The great trochanter is large and has a very rugose surface, but it has no such antero-posterior extension, does not rise so high and is not so pointed as in the existing forms of *Canidæ*. In consequence of this shape of the great trochanter, the digital fossa is smaller and much shallower than in the cats or recent dogs. From the great trochanter a sharp and prominent ridge, the *linea aspera externa*, descends along the external border of the shaft. Whether a third trochanter was present cannot yet be definitely determined, because in the only two femora preserved in the collection, the outer edge of the shaft is broken away at the point where the third trochanter would be, if present. In all probability, however, *Daphænus* did possess this trochanter, at least, in rudimentary form, as may be inferred from the analogy of the sabre-tooth *Dinictis*, and still more from the little contemporary dog, *Cynodictis*, which in many respects approximates the structure of the modern *Canidæ* more closely than does *Daphænus*. The lesser or second trochanter is larger, more prominent, and of more decidedly conical shape than in the recent species of either *Canis* or *Felis*.

The shaft of the femur is long, slender and nearly straight, though slightly arched toward the dorsal or anterior side; it differs from that of the modern dogs in its lesser curvature, and in broadening and thickening more gradually toward the distal end, and from that of the true cats in being more slender and of more nearly cylindrical shape. The rotular trochlea is rather narrower transversely than in the true cats, or even than in *Dinictis*, but is characterized by the same shallowness, and resembles that of the latter genus in its shortness vertically and lack of prominence. Transversely, the groove is but slightly concave, and it has much less prominent borders than in the existing species of *Canis*; these borders are slightly asymmetrical, the external one rising a little higher and being a trifle more prominent than the internal. A decided difference from both *Canis* and *Felis* consists in the fact that the trochlea hardly projects at all in front of the plane of the shaft, the anterior face of the latter gradually swelling to the level of the groove. In both of the recent genera mentioned, and especially in the canines, the trochlea projects prominently in advance of the shaft.

The femoral condyles are feline rather than canine in shape; they are small and of nearly equal size, though the outer one is slightly the larger of the two, and project much less strongly behind the plane of the shaft than in *Canis*. They are also less widely separated and less expanded transversely than in the latter genus. As in so many features of the limb bones, the whole distal end of the femur is more like that of *Dinictis* than it is like the corresponding part of the modern dogs or cats. In *Dinictis*, however, the rotular groove is shorter proximo-distally and broader, and the condyles are even less prominent.

The *patella* is very different from that of the recent *Canidæ*, in which group this bone is small, narrow and thick, but has more resemblance to that of *Dinictis*. It is quite broad, but very thin in the antero-posterior dimension; the anterior face is more roughened than in the *Machairodont* genus and the proximal end is more pointed, not so abruptly truncated. The facet for the rotular trochlea of the femur is, in correspondence with the shallowness of that groove, but slightly convex transversely and slightly concave proximo-distally.

The *tibia* (Pl. XX, Figs. 19, 20) is relatively short and slender, and bears considerable resemblance to that of *Dinictis*, more than to that of *Canis*. The proximal facets for the femoral condyles are small and but little concave; the outer facet is somewhat larger than the inner, and projects farther beyond the line of the shaft, both posteriorly and laterally. On the distal side of the overhanging shelf thus formed is a facet for the head of the fibula, which is much larger than in the recent dogs and more rounded in shape than in *Dinictis*. The spine of the tibia is very low and is more distinctly bifid than in the *Machairodont* genus, though much less so than in *Canis*. As in the former, the cnemial crest is not very strongly developed; it is far less prominent than in the existing *Canidæ* and does not descend so far upon the shaft as in them.

The tibial shaft is slender and nearly straight, not displaying the lateral and antero-posterior curvatures seen in *Canis*; proximally the shaft is of trihedral section, becoming approximately cylindrical below and transversely oval at the distal end. The latter is shaped much as in *Dinictis* and is conspicuously different from that of *Canis*; the astragalar facets are less deeply incised, and the intercondylar ridge is less elevated than in the latter, but the facets are deeper and the ridge higher than in the *Machairodont*, in correlation with the deeper grooving of the astragalus. The large transverse sulcus, which in the recent dogs invades these astragalar facets, is not shown in *Daphænus*. The internal malleolus is very large and resembles that of *Dinictis*, save that its posterior border is more inclined and the process is thus distally somewhat narrower. The sulcus for the posterior tibial tendon is very distinctly marked, more so than in *Canis*. The

distal fibular facet is quite large, being much as in *Dinictis* and consequently much larger than in the recent *Canidæ*.

The *fibula* (Pl. XX, Figs. 19, 20), which is greatly reduced in the modern dogs, is in *Daphænus* much stouter and has heavier ends, both proximal and distal. In *Canis* these ends have the appearance of being reduced and simplified from the condition seen in the White River genus. In the latter the proximal end of the fibula is relatively very large, especially in the fore-and-aft dimension, in which it considerably exceeds that of *Dinictis*, though the excess is principally due to a large tuberosity which projects from the hinder border, and which is present, though much less prominent, in the *Machairodont*. The facet for the head of the tibia is longer antero-posteriorly and narrower transversely than in the latter, forming a long, narrow, irregular oval. The shaft of the fibula is slender, though very much thicker both actually and proportionately than in *Canis*, and has about the same proportions as in *Dinictis*; it is laterally compressed, the principal diameter being the antero-posterior one, and of oval section, though its size and shape vary from point to point in an irregular fashion.

The distal end of the fibula resembles that of *Dinictis*, though it is somewhat smaller, in proportion to the length of the bone. The enlargement is both antero-posterior and transverse and gives rise to a very stout outer malleolus, at the postero-external angle of which is a deep sulcus for the peroneal tendons. The distal tibial facet is rather larger than that of *Dinictis*, while the surface for the astragalus is somewhat smaller, the two together making a high narrow band.

Measurements.

	No. 11421.	No. 11424.	No. 11423.
Femur, length (fr. head)			0.195
“ breadth of proximal end.....			.044
“ “ distal end.....			.038
“ “ rotular groove.....			.014
Tibia, length .....		.149	
“ breadth of proximal end .....		.031	.036
“ “ distal end.....	.021	.021	.025
Fibula, ant.-post. diameter prox. end .....			.019
“ “ “ dist. “ .....	.0145		.017

VII. THE PES (Pl. XX, Figs. 21, 21a, 22).

The *pes*, which displays structures of the highest interest, is much better represented in the collection than the manus and may be more adequately described. As a pre-

liminary, it will be useful to cite Schlosser's account of the salient characteristics of the hind foot among the recent *Canidæ*.

“Die Anordnung der Tarsalien und Metatarsalien weicht natürlich weniger ab von jener der übrigen Carnivoren als jene der Carpalien und Metacarpalien, doch finden wir auch hier immerhin einige nicht unwesentliche Modificationen. Es hat sich das Naviculare ziemlich beträchtlich verschmälert, so dass es nicht mehr die Aussenseite der unteren Astragalus-Partie umhüllen kann. Das Metatarsale II, das sonst nur von zwei Punkten mit dem Mt. III in Berührung kommt, legt sich hier seiner ganzen Breite nach an das Oberende desselben. In Folge der Verkürzung des Tarsus ist auch der aufsteigende Fortsatz des Mt. V sehr kurz geworden. Die Phalangen haben gleich den Metapodien nahezu quadratischen Querschnitt, die Krallen sind sehr spitz, aber wenig gebogen, haben jedoch ziemlich bedeutende Länge. Die Hunde sind die ausgesprochensten Zehengänger unter allen Carnivoren” ('88, p. 22).

In *Daphænus* the *astragalus* is decidedly different both from the astragalus of *Dinictis* and from that of *Canis*, but approximates more the latter. The trochlea is low and but moderately grooved, decidedly more than in *Dinictis*, but less than in the modern dogs, and the articular surface does not descend so far upon the neck as in the latter. The trochlea is asymmetrical, the outer condyle considerably exceeding the inner in size. The neck of the astragalus is much longer than in *Hoplophoneus*, *Dinictis*, or even than in *Canis*, and is directed more strongly toward the tibial side of the foot; the head is depressed, but very convex. The external calcaneal facet is hardly so large or so oblique in position as in *Dinictis*, but it is more like the facet seen in that genus than like the facet of *Canis*. The sustentacular facet is shorter and wider than in the latter, and the sulcus separating it from the external facet is very much shallower. In *Dinictis* the sustentacular facet has a posterior concave prolongation, such as is not found in *Daphænus*, nor does the latter possess the distal accessory facet for the calcaneum which is so distinctly shown in *Canis*. The navicular facet is depressed, but very convex, and there is a small facet for the cuboid.

The *calcaneum* is more like that of *Dinictis* than that of the recent dogs; though the tuber calcis is longer, thinner and more compressed than in either of those groups, and its dorso-plantar diameter is more uniform, increasing less toward the distal end; its free end is less thickened and more deeply grooved by the sulcus for the Achilles tendon. Along the outer edge of the dorsal border is a quite deep and conspicuous groove, which occurs also in *Dinictis*, but not in *Canis*. The external astragalar facet is very like that of the Machairodont, being more angulated and more oblique in position than in the modern dogs, presenting inward as much as dorsally. The sustentaculum also resembles that of *Dinictis* in being less oblique, much more prominent and in having its facet much

more widely separated from the external astragalar facet than in *Canis*. In the latter genus occurs a third astragalar facet, which is distal to the sustentaculum, and which is found in neither *Dinictis* nor *Daphænus*. The distal end of the calcaneum is occupied by the large cuboidal facet, which is more regularly oval in outline and much more deeply concave than in the existing forms of *Canidæ*. In these forms we find a facet for the navicular, which adjoins and forms a right angle with the accessory astragalar surface already mentioned, but is not present in either of the White River genera. On the external side of the calcaneum, near the distal end, is a prominent projection for ligamentous attachment. This process is not present in *Canis*, but it recurs in *Dinictis*, less markedly in *Hoplophoneus*, and is found in many of the recent viverrines, mustelines and raccoons.

The *cuboid* is not peculiar in any noteworthy way; it is longer proximo-distally than in *Dinictis* and is proportionately narrower and thinner (*i. e.*, in the dorso-plantar diameter). The long, thick and rugose ridge which on the fibular side of the bone overhangs the sulcus for the peroneal tendons is more prominent, especially on the plantar face, than in the *Machairodont*, but lacks the great, rugose plantar protuberance, which occurs in the recent *Canidæ*. The facet for the calcaneum is more convex than in *Dinictis*, very much more so than in *Canis*, in which this surface is almost plane. On the tibial face of the cuboid are three facets, a narrow proximal one for the navicular, and a median and minute distal facet for the ectocuneiform. The facet for the head of the fourth metatarsal is very much more concave than in the modern dogs, while that for mt. v is smaller than in the recent forms, and lateral rather than distal in position.

The *navicular*, as compared with that of *Canis*, is short proximo-distally, but broad transversely, not having undergone the reduction in width which Schlosser mentions as characteristic of the recent members of the family. The astragalar facet is not more concave than in the latter, and there is no such stout tubercle on the plantar side of the bone as occurs in them. Two very small facets articulate with the cuboid, one near the dorsal and the other near the plantar border of the fibular side. The distal facets for the three cuneiforms have nearly the same shape and proportionate size as in *Canis*, but they are more in the same transverse line, the surface for the entocuneiform being less displaced toward the plantar side.

The *entocuneiform* is of similar shape, but relatively better developed than in *Canis*, as would naturally be expected from the presence of a complete hallux in *Daphænus*. The bone is long proximo-distally, thick antero-posteriorly, and narrow, though broader than in *Canis*, and its proximal and distal facets, for the navicular and first metatarsal respectively, are relatively larger and more concave. The only other facet is an obscurely marked one on the tibial side for the mesocuneiform.

The *mesocuneiform* is a very small, wedge-shaped bone, broadest dorsally and thinning to an edge on the plantar side. The navicular facet is concave and very different from the curious oblique surface which we find in *Dinictis*. As is well-nigh universal among the Carnivora, the proximo-distal diameter of this bone is much less than that of either of the two adjoining cuneiforms, an arrangement which allows the head of the fourth metatarsal to rise above the level of the first and third.

The *ectocuneiform* is, as usual, much the largest of the three, though it is not so large proportionately as in *Dinictis*. The shape of this element is very much as we find it in *Canis*, but with certain minor differences. Thus, the proximal end is less extended in the dorso-plantar diameter, and the navicular facet is more concave; the plantar tubercle has a more constricted neck and enlarged, rugose head; the facets on the tibial side for the mesocuneiform and second metatarsal, and on the fibular side the inferior facet for the cuboid are more distinctly developed, while the distal facet for mt. iii is more concave and has a shorter plantar prolongation.

As a whole, the character of the tarsus is rather more machairodont, or viverrine, than canine. A conspicuous difference from the tarsus of the modern *Canidæ* is to be seen in the fact, that the articulations which in the latter are nearly plane (*e. g.*, the cubo-calcaneal) in *Daphænus* retain their more primitive concavo-convexity.

The *metatarsus* consists of five members, which are longer and relatively more slender than the metacarpals, though an exact comparison between the two cannot yet be made, because the collection contains no specimens in which both metacarpals and metatarsals are represented by anything more than fragments.

The *first metatarsal* is considerably longer and stouter than the corresponding metacarpal. In this case we can determine the true proportions, for of the species to which the finely preserved hind foot (Pl. XX, Fig. 21) belongs, *D. hartshornianus*, we also possess a pollex, though associated with a different specimen. The almost exactly similar skulls of the two individuals show that the animals were of approximately equal size. The head of mt. i is enlarged in both the transverse and dorso-plantar diameters, and bears a roughened tubercle upon the plantar side. The proximal facet, for the entocuneiform, is large, and strongly convex antero-posteriorly, nearly plane transversely; no other facets are visible on the proximal end. The shaft is slender and arched toward the dorsal side; in section it is transversely oval, expanding somewhat at the distal end, where the breadth is increased by the prominent tubercles for the lateral ligaments. The distal trochlea is small, but well developed, and of irregularly spheroidal shape, with plantar carina. The first metatarsal of *Dinictis* is like that of *Daphænus*, and certain viverrines, such as *Cynogale*, also have a hallux of much the same proportions, but in all the recent *Canidæ*, with the exception of certain domesticated breeds, mt. i is reduced to a nodule.

The *second metatarsal* is much longer and stouter than the first, but it is much shorter and weaker than mt. ii in *Canis*, and rather resembles that of the viverrine genus *Cynogale*, though it does not have the peculiar shape of the proximal end which characterizes that genus. In *Dinictis* mt. ii is somewhat heavier than in *Daphænus*, but is otherwise similar. In the latter the proximal end of mt. ii rises considerably above the level of mt. i and iii, owing to the shortness, proximo-distally, of the mesocuneiform, and is firmly wedged in between the ento- and ectocuneiforms, an arrangement common to all families of the fissipedes and already general among the creodonts. On the fibular side is a wedge-shaped projection which is received into a corresponding depression on mt. iii, thus making a very firm and close connection between the two bones. Above this projection are two facets for the tibial side of the ectocuneiform, one near the dorsal border and the other on the plantar projection. The shaft is straighter than in *Canis*, but is slightly arched dorsally, the distal end not curving toward the tibial side, as it does in the modern genus. In section the shaft is transversely oval, while in the recent dogs it has become trihedral for most of its length, owing to its close approximation to the shaft of mt. iii. The distal trochlea resembles that of *Dinictis* and differs from that of *Canis* in its more spheroidal and less cylindrical shape, and in its demarcation from the shaft by a deep depression; the lateral ligamentous processes are likewise more symmetrically developed.

The *third metatarsal* is much longer and stouter than the second, the difference between the two being greater than in *Dinictis* or the viverrines, or even than in *Canis*. The proximal end bears a facet for the ectocuneiform, of the usual shape, but the plantar prolongation of this facet is shorter and broader than in the last-named genus, and it resembles that of *Dinictis* in being oblique to the long axis of the bone, inclining decidedly toward the tibial side of the foot. The tibial side of this facet is deeply incised to receive the wedge-shaped prominence of mt. ii, an incision which does not appear in the recent dogs, but occurs, though somewhat less conspicuously, in *Dinictis*. On the fibular side are two facets for mt. iv; one near the dorsal border, which is a deep spherical pit, and the other a small, plane surface placed upon the plantar prolongation of the head. The shaft, when viewed from the front, appears quite straight, but when looked at from the side is seen to have a slight curvature toward the dorsal side. The distal end displays the same differences from *Canis* as do the other metatarsals.

The *fourth metatarsal* forms a symmetrical pair with the third, very much as it does in the recent dogs and cats, though in *Daphænus* they are relatively shorter and weaker. In *Canis* these two metatarsals are closely pressed together for most of their length, and their shafts have thus acquired a more or less trihedral section, with the approximate surfaces flattened, while the distal ends curve away from each other, somewhat as in

Poebrotherium. In *Daphænus* it is only the proximal portions of the two shafts which are thus closely pressed together; for the greater part of their length they are not in contact, and thus preserve the primitive oval section. As their divergence is due to the relative positions of the tarsal bones, there is no necessity for the lateral curvature of the distal ends. The two metatarsals are very closely interlocked and in much the same fashion as in *Canis*. On the head of mt. iv are two facets for mt. iii, of which the dorsal one is a stout hemispherical prominence, which is received into the pit on the head of mt. iii, already described. The plantar facet is actually upon the plantar rather than on the tibial face of the bone; the prolongation from the head of mt. iii extends around and embraces this facet, and by means of the double articulation a very firm interlocking of the two bones is effected. On the fibular side of mt. iv is a large and deep depression which receives the projection from mt. v. The facet for the head of the latter is large, slightly concave, and continues without interruption from the dorsal to the plantar border, while in *Canis* there are two distinct and quite widely separated facets. The shaft resembles that of mt. iii, but is somewhat more slender. In both of these metatarsals the distal carina is placed symmetrically with reference to the trochlea, but is less compressed and prominent than in *Canis*.

The *fifth metatarsal* is not completely preserved in any of the specimens, the only representative of it being the proximal end, belonging to a large individual of *D. vetus* (No. 11423). As the specimen is incomplete, nothing can be determined respecting its length, but probably this was equivalent to that of mt. ii, the two forming a symmetrical pair, much as in *Dinictis*, though mt. v, so far as it is preserved, seems to be somewhat the stouter of the two. On the fibular side of the head is a very prominent projection, ending in a roughened thickening, and directed obliquely outward and upward, the "ascending process" (aufsteigender Fortsatz) of which Schlosser speaks in the passage already quoted. In the recent dogs this process is very much reduced, while in *Dinictis* it is of quite a different shape. In the Machairodont the process is a long and prominent ridge, extending along the whole dorso-plantar thickness of the head, and projects much more proximally than externally, while in *Daphænus* it is a blunt hook which projects more outward than upward. The Machairodont *Hoplophoneus* has the process developed in very much the same way as in *Daphænus*.

The facet for the cuboid differs from that of *Canis* in being quite concave transversely and in presenting as much toward the tibial side as it does proximally, while in the modern genus the facet is small, plane, subcircular in outline and altogether proximal in position. On the tibial side is a rounded protuberance which fits into the pit on the head of mt. iv; this protuberance is more prominent than in *Canis* and decidedly more so than in *Dinictis*. What little of the shaft is preserved is transversely oval in section, with a

sharp ridge running down the fibular side, and is thus quite different from the trihedral section, with flattened tibial side, which is found in *Canis*, and is much more like the corresponding metatarsal of *Dinictis*.

The parallel arrangement of the metatarsals which we observe in the modern *Canidæ* is in *Daphænus* replaced by a radiating arrangement, the bones diverging toward the distal end. This distal divergence is, however, less decided in the pes than in the manus.

The *phalanges* display a very curious and surprising combination of characters. They are long, both actually and proportionately; compared with the tibia as a standard, they have about the same length as in the recent species of *Canis*, but they are decidedly longer than in that genus when compared with the length of the metatarsals.

A *proximal phalanx* of one of the median digits is long and depressed, but quite strongly arched upward or dorsally. The metatarsal facet has quite a different shape from that seen in *Canis*, the transverse diameter being relatively greater and the dorso-plantar less. The facet is also somewhat more oblique to the long axis of the phalanx, presenting rather more dorsally and less entirely proximally; the notch for the metatarsal carina is less deeply incised. Similar differences are observable in the body of the bone; its breadth being proportionately greater and its thickness less. The distal trochlea, which in *Canis* describes a semicircle from the dorsal to the plantar surface, is in *Daphænus* much more restricted, projecting less prominently from the plantar side and not reflected so far upon the dorsal face. On the other hand, this trochlea is more deeply cleft in the median line than in the modern genus and the tubercles for the attachment of the phalangeal ligaments are larger.

In all the differences from the modern *Canidæ* which have been mentioned, we may observe resemblances to the corresponding phalanx of *Dinictis*, in which the bone is somewhat shorter and broader than that of *Daphænus*, and has rather more prominent ligamentous tubercles, but is otherwise very like it.

The proximal phalanges of the lateral digits differ from those of the median pair only in being shorter, more slender and less symmetrical, and in having a lateral curvature which becomes very pronounced in the hallux.

The *second phalanx* is of about the same length, with reference to the first, as in *Canis*, but is broader, more depressed, and more asymmetrical than in that genus. The proximal facet, for the first phalanx, is more distinctly divided into two depressions by a more prominent median ridge, and the beak-like process of the median dorsal border is much more pronounced. The distal trochlea is reflected farther upon the dorsal side and projects more from that side, but extends less upon the plantar face; it is thus more convex in the dorso-plantar direction, but much less concave transversely than in *Canis*.

The asymmetry of this phalanx is quite marked: its tibial side is straight, while the fibular border is quite concave, and the dorsal surface is hollowed, or cut away, near the distal end, *allowing a retraction of the claws, to a limited extent*, as may be readily seen when the second and third phalanges are put together. This asymmetry of the second phalanx is much less conspicuous than in *Dinictis*, not to mention the modern felines, but it is, nevertheless, unmistakable and is certainly one of the most surprising features in the whole structure of *Daphænus*.

That an animal with the skull and dentition of a primitive dog should prove to possess even imperfectly retractile claws is not what our previous knowledge of the early carnivores would have led us to expect. So unlooked for was this character, that at first I was strongly inclined to believe that the association of the hind foot shown in Pl. XX, Fig. 21, with the skull of *D. hartshornianus* was an accidental one, and that the pes must belong to some genus of felines or Machairodonts as yet unknown. Fortunately, however, the collection contains a number of other individuals with more or less well-preserved hind feet, and the agreement among them all is complete. Curiously enough, the characteristic second phalanges are preserved only in connection with the specimen figured, but other specimens have parts of the tarsus, metatarsus, proximal and ungual phalanges, and a comparison of them shows that the reference of this particular hind foot is not open to question. The fact that the pes and the skull were found enclosed in the same block of matrix corroborates this inference, though, of course, such a fact is not of itself entirely conclusive.

The *ungual phalanx* is hardly less peculiar than the second, being short, very much compressed laterally, and bluntly pointed; it is very little decurved and has a plainly marked groove on the plantar face near the distal end. The narrowness, compression and straightness of this claw are in very decided contrast to the heavy and strongly decurved ungual phalanges of the modern *Canidæ*, though among the latter there is considerable variation in these respects. The articular surface for the second phalanx is much more strongly concave than in *Canis*, permitting a greater freedom of motion in this joint, as was necessary in order to provide for the retraction of the claw. The subungual process is not so large as in the modern genus and does not project so prominently upon the plantar face of the bone, but it is produced much farther proximally, extending beneath the distal end of the second phalanx, when the two are in their natural position. The long hood which envelopes the base of the claw is of about the same size and shape as in *Canis*, though the space between this hood and the body of the ungual phalanx is narrower. The ungual phalanx of *Dinictis* is shorter, more compressed, but deeper in the dorso-plantar diameter than in *Daphænus*, and has a decidedly larger subungual process, in correlation with the more complete retractility of the claws. The

few specimens of these phalanges which I have seen are without the bony hood around the base of the claw, having much the appearance of the unguals in the viverrine genus *Cynogale*. It is possible that the apparent absence of the hood may be due to the breaking away of that delicate structure, but this does not seem very likely.

Measurements.

	No. 10546.	No. 11421.	No. 11424.	No. 11423.	No. 11425.
Calcaneum, length.....	0.045	0.044		0.051	0.055
“ dorso-plantar diameter.....	.016	.015		.020	.020
“ length of tuber.....	.031	.029		.036	.040
“ extreme distal breadth.....	.017	.017		.022	.022
Astragalus, length.....		.027		.031	.031
“ proximal breadth.....		.018		.021	.022
“ width of head.....		.014		.016	.019
Cuboid, height.....		.015	.016		
“ width.....		.011	.012		
Navicular, width.....		.017		.019	
Ectocuneiform, width.....		.010		.010	
Metatarsal i, length.....		.031			
“ breadth prox. end.....		.009		.010	
“ “ dist. “.....		.007			
Metatarsal ii, length.....		.044			
“ breadth prox. end.....		.006		.007	
“ “ dist. “.....		.009			
Metatarsal iii, length.....		.054			
“ breadth prox. end.....		.009		.011	
“ “ dist. “.....		.0105			
Metatarsal iv, length.....		.056			
“ breadth prox. end.....		.006			
“ “ dist. “.....		.010			
Metatarsal v, breadth prox. end.....				.011	

The species of *Daphænus* hitherto recognized are three in number, two of them, *D. vetus* Leidy and *D. hartshornianus* Cope, from the White River stage, and the third, *D. cuspidigerus* Cope, from the John Day. Two additional species are described in the sequel, one of which, however, can be referred only provisionally to the genus, until more complete material has been obtained, though the species in question is evidently very closely allied to *Daphænus*, if not actually referable to it.

DAPHÆNUS VETUS Leidy.

Daphænus vetus Leidy, *Proc. Acad. Nat. Sci. Phila.*, 1853, p. 393. *Amphicyon vetus* Leidy, *ibid.*, 1854, p. 157; 1857, p. 90. *Extinct Mamm. Fauna of Dakota and Nebraska*, pp. 32, 369. Cope, *Tertiary Vertebrata*, p. 896.

This species has a skull about equal to that of the coyote (*Canis latrans*) in size,

but the vertebræ are much larger and the tail is longer and stouter. The tubercular molars of both jaws are relatively larger than in the other species. The inferior sectorial has a low anterior blade, and the internal cusp of its talon is reduced in size. The horizontal ramus of the mandible is long and slender and has a nearly straight inferior border. White River.

DAPHÆNUS HARTSHORNIANUS Cope.

Daphænus vetus Leidy, *Amphicyon vetus* Leidy, in part, *loc. cit.* *Canis hartshornianus* Cope, *Synopsis New Vert. from Colorado*, 1873, p. 9. *Ann. Rept. U. S. Geolog. Surv. Terrs.*, 1873, p. 505. *Amphicyon hartshornianus* Cope, *Tertiary Vertebrata*, p. 896.

This species is somewhat smaller, and the tubercular molars of both jaws are proportionately smaller than in the preceding species; the anterior triangle of the lower sectorial is high and acute, and its talon is basin-shaped, with the internal cusp as large as the external. The horizontal ramus of the mandible is straight and slender. Both this species and the preceding one have been found in the middle division (Oreodon beds) of the White River formation, but not as yet, to my knowledge, in the lower (Titanotherium beds) or the uppermost division (Protoceras beds).

DAPHÆNUS CUSPIGERUS Cope.

Canis cuspidigerus Cope, *Proc. Amer. Phil. Soc.*, 1878, p. 70. *Amphicyon entoptychi* Cope, *ibid.*, 1879, p. 372. *Amphicyon cuspidigerus* Cope, *Bull. U. S. Geolog. Surv. Terrs.*, Vol. VI, p. 178; *Tertiary Vertebrata*, p. 898.

D. cuspidigerus is much the smallest known species of the genus. The sagittal crest is very short and inconspicuous; the cranium is fuller and more rounded, the postorbital constriction is shallower and more anterior in position than in the White River species, and the mandibular ramus is nearly straight and very slender. The inferior sectorial is very robust and has a low anterior triangle and basin-shaped heel. John Day stage.

DAPHÆNUS FELINUS, sp. nov.

The inferior dental series of this species slightly exceeds in length that of *D. vetus* and the sectorial is larger. The lower tubercular molars are inserted in the border of the ascending ramus of the mandible, and, judging from the alveoli, were reduced in size. The horizontal ramus is not much longer, but much heavier than in *D. vetus*, and has a more sinuous ventral border, which rises more beneath the masseteric fossa. The limb

bones and vertebræ are somewhat larger and heavier than those of *D. vetus*, and the neural spines of the lumbar vertebræ are very high and incline strongly forward. In size *D. felinus* is the largest and most massive species of the genus. The type specimen consists of a fragmentary skeleton (No. 11425) with which are associated both mandibular rami, and which was found by Mr. Gidley in the Oreodon beds of Hat Creek Basin, Neb., in 1896.

? *DAPHÆNUS DODGEI*, sp. nov.

As already intimated, the reference of this species to *Daphænus* cannot yet be definitely made, but the material so far obtained, consisting of lower jaws, affords no sufficient ground for separating it from that genus. The inferior dental series is relatively short; the premolars are much smaller, especially in the antero-posterior dimension, than those of the later species from the Oreodon beds, but, at the same time, they are proportionately thick and heavy. The lower sectorial has a low, massive anterior triangle and a basin-shaped talon, with the inner cusp much smaller than the outer. The horizontal ramus of the mandible is short, but relatively much stouter than in any of the other species, and has a more sinuous ventral border, which rises steeply toward the angle.

This species is dedicated to my friend, Mr. Cleveland H. Dodge, of New York, whose liberality has made possible much of the work undertaken by the Princeton Museum and to whose kindness I am under the greatest obligations.

The type specimen (No. 11422) was found by Mr. Gidley in the Titanotherium beds of the Hat Creek Basin.

Before proceeding to an examination of the next genus of White River *Canidæ*, *Cynodictis*, it will be necessary to introduce a brief description of a species which has been found in the Uinta stage of the upper Eocene (or lower Oligocene) and which apparently represents the forerunner of *Daphænus*, though more perfect specimens will be required before its position in the canine phylum can be definitely determined.

MIACIS Cope.

This form differs from *Daphænus* in the construction of the upper tubercular molars. M^1 has an exceedingly broad external cingulum, forming at the antero-external angle a very large projection; the internal unpaired cusp found in *Daphænus* and in all subsequent genera of the *Canidæ* is absent in both m^1 and m^2 . The upper sectorial is of very primitive and undeveloped character in the shortness of the posterior cutting ridge and the great transverse breadth of the crown.

MIACIS UINTENSIS Osborn.

Bull. Am. Mus. Nat. Hist. N. Y., Vol. VII, p. 77.

Size rather less than that of *D. hartshornianus*; upper sectorial relatively small and tubercular molars large; premolars short and thick.

Measurements.

	MM.
Length, p ³ to m ² inclusive.....	37
P ³ length.....	7
P ⁴ length.....	11
P ⁴ width.....	11
M ¹ length.....	11
M ¹ width.....	16
M ² length.....	9
M ² width.....	7.5

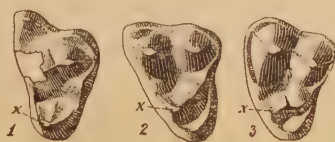


FIG. A.—First upper molar of the left side:

1, of ?*Miacis uintensis*. 2, of *Daphænus hartshornianus*. 3, of *Canis latrans*. *x*, cusp usually regarded as the protocone.

If *Miacis* be rightly regarded as having a place in the canine phylum, then the structure of its upper tubercular molars is of great interest and will require a revision of the current views concerning the homologies of the cusps in the upper molars of the dogs. In *Canis*, according to the usual interpretation, m¹ is composed of two external cusps, the para- and metacones, and at the apex of the triangle of which the para- and metacones form the base, an unpaired internal cusp, the protocone, with the proto- and metaconules on the anterior and posterior sides of the triangle respectively. Internal and somewhat posterior to the protocone is a large crescentic cusp, which is commonly regarded as an enlargement of the cingulum, although in unworn teeth a faint cingulum may be traced all around this crescentic cusp and is continuous with the prominent cingulum which bounds the anterior wall of the crown. If this interpretation of the cusps be correct, and further, if *Miacis* is ancestral to the *Canidæ*, then m¹ in the Uinta genus is *without a protocone* and has only the para- and metacones, minute conules and the large inner crescentic cusp. It seems much more rational to conclude that the latter is really the protocone and that the cusp which has been so named in *Canis* is an additional element subsequently developed. In *Daphænus* this inner crescentic cusp and

the conules are relatively smaller than in the modern representatives of the family, which goes to confirm the conclusion that the name protocone should be given to the innermost cusp and that in *Canis* the middle part of the crown has undergone a special increase in complexity.

CYNODICTIS Gervais.

Amphicyon Leidy, Marsh, in part. *Canis* Cope, in part. *Galecynus* Cope, non Owen.

It is with much hesitation that I employ the name of this European genus for North American species, for there are certain constant differences which Schlosser ('88,) appears to consider as being of generic value. An actual comparison, however, of the American forms with specimens of *Cynodictis lacustris*, Gervais' type species, and from the typical locality, Débruges, has failed to reveal any important differences between the two, and, therefore, for the present at least, I retain the name of the European genus for the American species, which are very closely allied, if not positively referable to it.

The structure of these small carnivores, especially of the John Day species, is much better known than that of *Daphænus*, though our knowledge of the White River species has hitherto remained very incomplete, and even of the better known John Day forms only Cope's brief descriptions have as yet been published. Despite the fact that *Cynodictis* is one of the commoner White River fossils, well-preserved specimens are comparatively rare and of these the greater part consist only of skulls. The bones of the skeleton are so small and so fragile that it is exceedingly difficult to obtain more than fragments of them. By dint of great care and attention paid to these small forms, Messrs. Hatcher and Gidley have succeeded in gathering some very fine specimens for the Princeton Museum, and others I owe to the kindness of Mr. John Eyerman. Together, these various individuals represent nearly all parts of the skeleton and enable us to reconstruct the animal and to compare it with the better preserved and more abundant species of the succeeding John Day formation.

I. *The Dentition.*

The dental formula of *Cynodictis* is: I $\frac{3}{3}$, C $\frac{1}{1}$, P $\frac{4}{4}$, M $\frac{2}{3}$, differing from that of *Daphænus* only in the absence of the third upper molar.

A. *Upper Jaw*.—The incisors are very small, simple and antero-posteriorly compressed, giving them chisel-shaped crowns; they increase in size from the first to the third, but the latter does not greatly exceed the others; not nearly so much, for example, as in *Canis* or *Daphænus*, and hardly more than in the viverrines. A very short diastema separates the lateral incisor from the canine.

The canine has a stout, gibbous fang, which produces a marked convexity upon the side of the maxillary; its crown is quite elongate and somewhat recurved and much com-

pressed laterally. The tooth is relatively smaller than in the recent dogs and thinner transversely, and has therefore quite different proportions from those seen in *Daphænus*.

The premolars increase in size posteriorly; in the unworn condition they have high, compressed, thin and very acute crowns, but in old individuals, without showing much appearance of wear, these teeth have low crowns, elongated in the fore-and-aft direction. The first premolar is very small and simple; it is inserted by a single fang and follows immediately behind the canine, without a diastema, which is a difference from *Daphænus*. The second premolar is much larger than p^1 ; it is implanted by two fangs and has a perfectly simple crown, without posterior basal tubercle, though the cingulum is thickened at that point. The third premolar is still larger, especially in the vertical height of the crown, and is distinguished by the presence of a posterior tubercle in addition to the thickening of the cingulum already found in p^2 . The fourth premolar is a very effectively constructed, though small, sectorial blade, being much more compressed and trenchant than in *Daphænus*. The anterior cusp of the shearing blade (protocone) is relatively higher and thinner and has a sharper point and edge than in the latter genus, and the posterior cutting ridge (tritocone) is better developed and more efficient. On the other hand, the internal cusp (deuterocone) is very much smaller (hardly larger proportionately than in *Canis*) and occupies a more posterior position. In the European species of *Cynodictis* the deuterocone is not so much reduced and is placed as far forward as in *Daphænus*.

The first molar is large, particularly in the transverse dimension, and is of subquadrate outline. The outer cusps are high and quite acutely pointed, and the central cusp (usually called the protocone) is lower and of crescentic shape, and the internal cusp is a broad, crescentic shelf, which occupies about the same position as in *Canis*. The conules are very small, but of nearly equal size, a difference from the modern genus, in which the metaconule is large, while the protoconule is rudimentary or absent, and even in *Daphænus* the posterior conule is much the larger of the two. The cingulum is very prominently developed upon the outer side of the tooth and forms a large projection at the antero-external angle, as in *Daphænus*, though not in *Canis*, a reminiscence of creodont ancestry.

In the John Day species, *C. geismarianus* and *C. lemur* and still more in *C. latidens*, the first upper molar has a much more distinctly quadrate crown, due to the enlargement of the metaconule, which has become as large as the central cusp, and to the more symmetrical development of the internal cusp (? protocone). In the typical European species, *C. lacustris*, on the contrary, the crown of this tooth retains a more trigonodont character.

The second molar is very small, being relatively much more reduced than in *Daphæ-*

nus. It is composed of the same elements as $m \frac{1}{2}$, but has a different shape, owing to the greater proportionate length, antero-posteriorly, of the inner portion of the crown. In appearance this tooth is a miniature copy of that of *Canis*.

B. *Lower Jaw*.—The incisors are very small and closely crowded together, so that the fang of $i \frac{2}{2}$ is pushed back out of line with the other two.

The canine, which is even more compressed laterally than the upper one, is long and recurved; it is separated from $p \frac{1}{1}$ by a very short diastema.

The first premolar is a very small, simple cone, inserted by a single fang. The second is much larger and is supported by two roots; it has an anterior basal cusp, which is formed by the cingulum and is subject to considerable variation, being much larger in some individuals than in others. The third premolar has a high, compressed and sharp-pointed crown and bears three accessory cusps, anterior and posterior basal cusps formed by the cingulum, and a third developed upon the posterior edge of the protoconid, very much as in *Canis*. The fourth premolar is slightly larger than $p \frac{3}{3}$ and has more distinctly developed accessory cusps, but on both $p \frac{3}{3}$ and $p \frac{4}{4}$ these cusps are subject to much variation and in some specimens they are feebly marked or even absent.

The European *C. intermedius* has very similar premolars to those of *C. gregarius*, and in both species the anterior basal cusps (which are not present in *Daphænus*) give a somewhat viverrine character to the dentition.

The first molar has a quite elevated anterior triangle, with a high, pointed protoconid and a well-developed paraconid, both of which are more compressed and trenchant than in *Daphænus*. The metaconid is smaller than in the latter and is placed lower down and more posteriorly, so that it is visible from the outer side, much as in the modern dogs. The heel is basin-shaped and is composed of a large, crescentic external cusp and a smaller internal cusp. In the European species may be observed certain differences in the structure of the lower sectorial from the White River form, though these differences are not great. In the Old World species the anterior triangle is higher and the protoconid less compressed, while the metaconid is larger and occupies a more elevated and anterior position; in other words, the anterior triangle resembles that of *Daphænus*. Another difference from the American forms consists in the presence of a second internal cusp in the heel of the sectorial, which may be observed in most of the individuals figured by Schlosser and Filhol. However, in a specimen of *C. lacustris* from Débruges, which the Princeton Museum owes to the courtesy of Prof. Gaudry, this second cusp is not visible. In perfectly unworn teeth of *Daphænus hartshornianus* a feeble indication of this second cusp may be seen.

The second molar is tubercular and of a narrow and elongate oval shape; in constitution it entirely resembles that of *Canis*; the paraconid has disappeared, while in

Daphænus it is still distinctly visible, though very small. The proto- and metaconids are of equal size and placed on nearly the same transverse line; these cusps are higher, more sharply pointed and more slender than in the recent *Canidæ*. The talon, which is somewhat lower than the anterior half of the tooth, retains a distinctly basin-like form. In the European species we find a more primitive character of $m \frac{1}{2}$ in the retention of the paraconid. The third molar is very small; it has an oval, roughened crown and is carried upon a single fang. As Cope has pointed out, this tooth is usually missing in the fossils, and occasionally a specimen is found which has not even an alveolus for it.

The dentition of *Cynodictis gregarius* is, on the whole, a little more modernized and advanced than that of the European representatives of the genus. This advance is shown in the reduction of the inner cusp of the upper sectorial; in the somewhat more quadrate outline of $m \frac{1}{2}$; in the less elevated shearing blade and more posterior position of the metaconid on the lower sectorial, and, finally, in the more complete reduction of the paraconid of $m \frac{1}{2}$. In the John Day species, especially in *C. geismarianus* and *C. latidens*, the departure from the European type is even more marked.

Measurements.

	No. 10493.	No. 10513.	No. 10939.	No. 11012.	No. 11382.	No. 11432.
Upper dentition, length I 1 to M 2			0.014	0.044	0.0435	0.0435
Upper canine, ant.-post. diameter.....			.005	.005	.005	.0045
“ “ transverse “ .....			.0035	.003		.003
“ premolar series, length.....			.025		.023	.025
“ molar series, length .....	.010	.010	.011	.010	.010	.010
“ P 1, length.....			.0035	.003	.003	.003
“ P 2, “ .....	.005		.0045	?.004	.0045	.003
“ P 3, “ .....	.0055		.005			.0055
“ P 4, “ .....	.010	.009	.009	.0095	.0085	.009
“ P 4, breadth .....	.006		?.004	.0055	.005	
“ M 1, length.....	.0065	.007	.006	.006	.006	.006
“ M 1, breadth.....	.009		.008	.008		
“ M 2, length.....	.0035	.003	.004	.004	.003	.003
“ M 2, breadth .....	.006		.006	.0055	.004	.005
Lower premolar series, length.....				.021	.019	
“ molar series, length.....	.017	.016		.017	.015	
“ P 1, length.....				.003	.003	
“ P 2, “ .....			.005	.005	.004	
“ P 3, “ .....	.0055		.005	.006	.005	
“ P 4, “ .....	.0065	.007	.006	.0065	.006	
“ M 1, “ .....	.010	.0095	.0095	.010	.009	
“ M 2, “ .....	.005	.005	.005	.005	.0045	
“ M 2, breadth .....	.003		.003	.0035		

II. THE SKULL (Pl. XIX, Figs. 11, 12).

The skull of *Cynodictis* is decidedly primitive and in general appearance resembles that of such viverrine genera as *Paradoxurus*, rather than that of the modern *Canidæ*. Among the latter the alopecoid series have skulls more resembling the type of *Cynodictis* than do the thooids, though the Brazilian bush-dog (*Icticyon*) is, on the whole, most like the fossil in the proportions of its skull.

In *Cynodictis*, as in *Daphænus*, the facial or preorbital region of the skull is very short and the cranial portion very long. The occiput is low and the upper contour of the skull rises steeply from the inion to about the middle of the parietals, whence it descends in an almost straight line to the anterior nares, the only departure from straightness being a hardly noticeable concavity or "dishing" of the nasals about midway in their length. In *Vulpes* the profile is quite similar, but the posterior rise from the occiput is much shorter and less steep, and the dishing of the nasals is more conspicuous. The sagittal crest is low and weak, and in the John Day *C. lemur*, the smallest species of the genus, the crest is replaced by a lyrate sagittal area. The cranium, though slender, elongate and contracting anteriorly, is relatively fuller and more capacious than in *Daphænus*, and the postorbital constriction, though much deeper, is as near the orbit as in the modern foxes, and is, therefore, much farther forward than in *Daphænus*. The John Day specimens, which Cope has referred to *C. gregarius* ('85, Pl. LXVIII, Fig. 6), have an even fuller cranium and shallower postorbital constriction, which should, perhaps, be a reason for separating these animals specifically from the White River forms. The muzzle in *Cynodictis* is very slender, but tapers gradually and is not so abruptly constricted at the line of the infraorbital foramina as in *Daphænus*. In the European representatives of the genus the skull is much like that of the American species, but is somewhat more primitive and like that of *Daphænus*. Thus, the muzzle is more abruptly constricted, and the postorbital constriction is deeper and occupies a more posterior position.

A more detailed examination of the skull brings out the following facts :

The *occiput* is low, very broad at the base and narrowing toward the summit less than in the large wolves, but more than in *Vulpes* or *Urocyon* ; a well-marked median convexity is produced by the vermis of the cerebellum. The crest of the inion is low and weak, much less prominent than in *Daphænus*. The foramen magnum differs somewhat in shape in the different individuals, being in some low and broad, and in others of subcircular outline, a difference which may, in part, be due to a slight crushing. The dorsal margin of the foramen projects much more prominently than in the recent *Canidæ*.

The *basioccipital* is long, broad and of nearly uniform width throughout ; it is

slightly concave transversely, but has a low median convexity, with very feebly developed keel, the convexity being much less prominent than in *Daphænus*.

The *exoccipitals* are low and wide and so convex in the median line that this portion projects much behind the sides. The condyles are low and depressed and are separated on the ventral side by a narrower, deeper and more V-shaped notch than in the modern wolves or foxes. The paroccipital processes are very small and project almost directly backward, as if to avoid the auditory bulla, with which they are not in contact at any point.

The *supraoccipital* is a large bone, both high and broad; dorsally it is reflected over upon the cranial roof, and in this region is thickened and diploëtic.

The *mastoid* is exposed quite extensively upon the occipital surface, somewhat more so than in the modern representatives of the family, and as the distance between the paroccipital process and the posttympanic process of the squamosal is greater than in the latter, the mastoid occupies a rather more lateral position. The mastoid process is very small, almost obsolete.

The *sphenoid* bones cannot be described, as none of the specimens allow the limits of these elements to be determined.

The *tympanic* differs in very important ways from that of *Daphænus*. In the first place it is inflated into a very much larger auditory bulla, filling out the entire fossa and leaving no part of the periotic exposed; and in the second place, the posterior chamber of the bulla is ossified and fused with the anterior chamber. The line of junction between the two elements which compose the bulla is very plainly marked by a groove upon the external surface, and shows the posterior chamber to be considerably the smaller of the two. I have not been able to detect any, even partial, septum between the two chambers, but such a septum as that of *Canis* may well have been present. The bulla is relatively as elongate as that of *Canis*, but is much narrower and more compressed, and therefore has a less inflated appearance. The external auditory meatus is a very large, oval aperture, without any tubular prolongation, the borders being flat, except the anterior one, which forms a more prominent lip than in *Canis* and partially conceals the postglenoid foramen. The auditory bulla of *Cynodictis* is thus thoroughly cynoid in development and displays no resemblance to the characteristic viverrine type.

The *parietals* are proportionately very large bones and make up the greater part of the sides and roof of the cranium. Throughout their length they unite to form a very low and weak sagittal crest, which becomes moderately prominent only at the concavity of the cranium formed between the occipital crest and the hinder wall of the cerebral fossa. Owing to the larger size and backward extension of the cerebral hemispheres, as well as to the lowness of the occipital crest, this concavity is shorter and much shallower

than in *Daphænus*. In some specimens, even aged ones, the anterior half of the parietals carries a very narrow sagittal area, rather than a crest, but only in the little *C. lemur* from the John Day does this area assume the lyrate form. This fact is of importance in determining the primitive or secondary nature of the sagittal crest, concerning which there has been some dispute.

The *frontals* form relatively as much of the cranial roof as in *Canis* and have, when viewed from above, an hour-glass shape, which is due to the deep postorbital constriction, though the depth of this depression varies considerably in different individuals. The postorbital processes are very small and owe their prominence entirely to the constriction. The forehead is slightly convex, both transversely and longitudinally, though in some specimens it has a narrow and shallow depression along the median line, such as is found, though much more distinctly, in modern species of both *Canis* and *Vulpes*. The forehead is bounded by the obscurely marked supraciliary ridges converging posteriorly to the sagittal crest, which is entirely upon the parietals, none of it being formed by the frontals. Anteriorly the frontals are emarginated to receive the narrow nasals, and send forward slender nasal processes, which are separated by short interspaces from the ascending rami of the premaxillaries. A noteworthy difference from *Daphænus* consists in the *absence of frontal sinuses*, in which respect *Cynodictis* agrees with the alopecoid series of the modern *Canidæ*, as *Daphænus* does with the thooid series. The significance of this fact will be discussed in a subsequent chapter.

The *squamosal* has a relatively small extension upon the side of the cranium, and this portion of it has a different shape from that seen in the modern dogs, the parietal suture descending very steeply forward from the occipital crest, while in the modern genera this suture pursues a nearly horizontal course. From the base of the zygomatic process to the posttympanic process of the squamosal runs a projecting shelf, which overhangs the auditory meatus and is much wider than in *Canis* or *Vulpes*, though not so broad as in *Cynodesmus*, *Hypotemnodon* or *Daphænus*. The posttympanic process is not larger than in *Canis*, but is made more conspicuous by the absence of any tubular meatus auditorius. The zygomatic process is relatively somewhat heavier than in *Vulpes*, and in shape and proportions much like that of the wolves, though not so strongly arched upward; anteriorly it extends to the postorbital process of the jugal. The glenoid cavity is broad and the postglenoid process is proportionately heavier, more extended transversely and its distal end is more curved forward than in *Canis*. There is no preglenoid ridge.

The *jugal* also resembles that of *Canis*, though it displays some differences. Thus, it is not quite so long as in the modern genus and does not extend so near to the glenoid cavity; it has a less decided upward curvature, and the postorbital angle (it can hardly be called a process) is even less conspicuous; the masseteric surface is broader, more lat-

eral and less inferior in position, and is bounded above by a distinct crest; the antero-inferior, or maxillary, process is shorter, and the ascending, or frontal, process is narrower, but extends farther upward along the margin of the orbit. As a whole, the zygomatic arch is of nearly the same proportionate length as in *Canis latrans*, but has a straighter fore-and-aft course, being much less strongly arched upward, though curving outward quite as decidedly from the side of the skull. This comparative shortness of the arch, in association with the very elongate cranium, is due to the anterior position of the zygomatic process of the squamosal, which is placed much farther in advance of the occipital condyle than in the recent members of the family.

The *lachrymal* forms but a very small portion of the anterior rim of the orbit and carries a rudimentary spine. Within the orbit the bone is relatively more extended and occupies a more elevated position than in the modern dogs, while the ascending or frontal process is much shorter; the lachrymal foramen is large and is farther removed from the frontal suture.

The *nasals* are short, narrow and slender, splint-like bones, which are convex transversely and very slightly concave antero-posteriorly; their general shape is much the same as in *Vulpes*, except for the much less distinct fore-and-aft concavity and their lesser elongation.

The *premaxillaries* are small; the alveolar portion is weak, in correspondence with the smallness of the incisors, and is not produced anteriorly in the spout-like form which characterizes *Daphænus*; the groove for the reception of the inferior canine is much less deeply incised than in the latter. The ascending ramus is long and slender, but forms a wider strip upon the side of the muzzle than in the last-named genus. The anterior narial opening is small, oval in shape and more oblique in position than in either *Canis* or *Vulpes*. The palatine processes of the premaxillaries are short and very narrow, and the incisive foramina are small. This portion of the palate has an entirely different appearance from that found in *Daphænus*; the premaxillaries are not nearly so much extended in front of the canines, the incisive foramina are shorter and have no such grooves extending forward from them; the spines are very slender and much shorter, reaching only to the canines and not to the line of p^1 , as they do in the larger genus. In most of these respects *Daphænus* is nearer to *Canis* and *Vulpes* than is *Cynodictis*.

The *maxillaries* are relatively very short, much shorter than in the existing genera, a statement which especially applies to the facial or preorbital portion. At the same time the vertical height is proportionately great. Except for the swelling produced by the root of the canine, the facial surface of the maxillary is simply convex, there being no distinctly marked fovea maxillaris. Owing to the shortness and height of the facial portion, its superior and anterior margin, formed by the sutures with the frontal, nasal and premaxillary, is more strongly curved and descends much more steeply in front than

in *Canis*. As in *Daphænus*, the infraorbital foramen is placed very near to the orbit, while in the modern genera it is much in advance of the orbit. The arrangement seen in *Cynodictis* is due chiefly to the anterior position of the orbit and in much less degree to the backward shifting of the foramen itself. The palatine processes of the maxillaries are short and narrow, corresponding to the shortness and slenderness of the muzzle, and they resemble those of *Daphænus* in being slightly concave transversely, with a faintly marked median ridge along the line of suture.

The *palatines* have nearly the same shape and proportions as in *Canis latrans* (though they are relatively somewhat narrower) and extend forward to the anterior edge of p⁴; the palatine notch is more deeply incised than in either *Canis* or *Vulpes* and is nearly as deep as in *Urocyon*. Only a single posterior palatine foramen is visible on each side. As a whole, the bony palate resembles that of *Canis* more than that of *Daphænus* in its much less abrupt narrowing at the level of the sectorials. The posterior nares have about the same shape and position as in *Vulpes* and have a similar median spine-like process on the anterior border.

The *pterygoids* terminate in longer, more distinct and more thickened hamular processes than in the recent genera, some of which, like *Urocyon*, have no vestige of such processes. From the descending process of the alisphenoid is given off a prominent lateral spine, which, in *Canis* and *Vulpes*, is represented only by a low ridge.

The *mandible* has a slender and compressed horizontal ramus, which tapers rapidly toward the anterior end; it forms a long symphysis with its fellow of the opposite side and curves very gently upward at the chin. The ventral border describes a somewhat sinuous course, curving downward beneath the sectorial, from which point it rises very gradually and regularly to the symphysis, while beneath the masseteric fossa it is concave. There is no trace whatever of the lobation which is found in so many of the existing *Canidæ*, both alopecoids and thooids. The ascending ramus, which forms an obtuse angle with the horizontal, has a proportionately smaller antero-posterior width than in *Daphænus*, though a greater one than in the modern genera; the coronoid process, in particular, is much narrower than in the former, and the sigmoid notch is wider than in the living forms. The masseteric fossa is very deeply impressed, but it has no such definitely marked upper boundary and it does not extend forward so far beneath the molars as in *Canis*, features of resemblance to the alopecoids. The angle is formed by a short, slender and blunt, hook-like process. The condyle, which is not in any way peculiar, is elevated much more above the level of the molar teeth than in *Daphænus*.

The *cranial foramina* are very minute and hence are often difficult to detect, save in exceptionally well-preserved specimens, a very slight degree of crushing being often sufficient to obliterate them. In general, they may be described as characteristically

cynoid. The condylar foramen is an opening, hardly larger than a pin-hole, which perforates the ridge running mesially from the paroccipital process; its position is just as in *Canis*. The foramen lacerum posterius is rather smaller than in existing representatives of the family, which is due to the greater proportionate elongation of the auditory bulla, and for the same reason the styloid foramen is less conspicuously displayed. An important difference from *Canis* and *Vulpes* consists in the presence of a well-defined external opening of the carotid canal, which grooves the inner side of the auditory bulla somewhat behind the middle of its course; it is much better shown in some specimens than in others. In the modern *Canidæ*, "the carotid canal is complete and of tolerable dimensions; but its external opening is not visible on the surface of the bulla, being deep in the foramen lacerum posticum" (Flower, '69, p. 24). The other carnivorous families, however, have the carotid canal with visible opening, but varying in position in the different groups.

The foramen lacerum medium and the Eustachian foramen are very much as in *Canis*, but the glenoid foramen is somewhat concealed by the prolonged anterior lip of the auditory meatus. The foramen ovale is a narrow slit which may be readily overlooked, and is closed by even a slight distortion of the skull. An alisphenoid canal is present, and the other openings, the optic, anterior lacerated and round foramina, are as in the recent cynoids. The whole structure of the cranial basis and its foramina are thus canine in character, with only a single difference, the distinctness of the carotid canal. There is nothing to suggest relationship with the viverrines.

Measurements.

	No. 10493.	No. 10513.	No. 10939.	No. 11012.	No. 11381.	No. 11382.	No. 11432.
Skull, length (fr. occ. condyles).....			0.092	0.092		0.086	0.089
Cranium, length (occ. condyles to preorbital border).....	.062	?.062	.064	.064		.059	.063
Face, preorbital length.....			.032	.030		.030	.028
Occiput, breadth across mastoid processes.....	.033	.034	.034	.038	.035	.032	.033
Brain case, greatest breadth.....	.031	.032	.032	.035	.033	.033	.033
Skull, width across zygomas.....	.052					.055	
Zygomatic arch, length.....	.042	.043	.043	.043		.042	.014
Face, width at p ⁴.....	.026	.026	.026			.030	.025
" " " canine.....			.016	.017		.018	.015
Mandible, length (fr. condyle).....			.063			.060	
" depth at m ₁.....	.009	.011	.011	.011		.010	
" " " p ₂.....			.010	.008		.007	
" thickness at m ₁.....	.0045	.0055	.0055	.005		.005	
" height of coronoid process (from ventral border).....	.027	.029	?.027			.029	
" height of condyle fr. angle.....	.014					.013	

III. THE BRAIN (Pl. XIX, Fig. 12).

The brain of *Cynodictis* has already been described by Bruce ('83, p. 41), but as I wish to consider it from a different standpoint, some account of it will be necessary. In this genus the brain is relatively smaller than in any of the recent *Canidæ*. The olfactory lobes are large and are left exposed by the hemispheres, with which they are connected by short and thick olfactory tracts. The cerebral hemispheres are pear-shaped, broad behind, but tapering rapidly forward, where they decrease in vertical as much as in transverse diameter. The frontal lobe is short, narrow and of small vertical depth, while the parietal lobe much surpasses it in every dimension; a transverse depression marks the boundary between the two. The temporo-sphenoidal lobe is also quite well developed and adds materially to the dorso-ventral diameter of the brain in this region. Posteriorly the hemispheres slightly overlap the lateral lobes of the cerebellum (which appears not to be the case in *Daphænus*), but leave the vermis entirely uncovered. The shape of the cerebrum is thus alopecoid rather than thooid in character. In the former series the hemispheres are wide behind and taper anteriorly, with slight incurvations at the sylvian and presylvian fissures, while in the thooids the cerebrum is narrower behind and at the presylvian fissure the sides are abruptly incurved almost at a right angle; the frontal lobes are much larger relatively than in the foxes (see Huxley, '80, pp. 245-247). The hemispheres of *Cynodictis* agree well in shape with those of the alopecoids, and when compared with the brain of the later and more advanced genus *Cynodesmus* from the John Day, the greater width of their posterior region is distinctly to be seen. The whole character of the skull makes it evident that *Cynodesmus* is a thooid, while both brain and skull structure approximate *Cynodictis* more to the alopecoids.

The hemispheres are very simply convoluted and the sulci are few, simple and short, though it should not be forgotten that the brain-cast very probably fails to reproduce all of the fissures. In the recent *Canidæ* the convolutions are numerous and complex, and the sulci pursue a remarkably curved course, giving to the convolutions, when seen from the side, the appearance of a succession of U-shaped, concentric coils, grouped around the sylvian fissure as a centre. In *Cynodictis*, on the other hand, the visible sulci are few, shallow, short and nearly straight. On the dorsal surface of the hemisphere only two fissures are to be observed, the lateral and the suprasylvian, the former of which is short and almost straight, dying away before it reaches the hinder part of the parietal lobe. If the coronal sulcus is present at all, it is in the same fore-and-aft line as the lateral, and has not the outward sweep around the crucial fissure which is so characteristic of *Canis*. No trace of the crucial fissure is preserved in the brain-cast, and if it was present in the brain, it must have been short, as is indicated by the straight course of the

lateral sulcus. The suprasylvian sulcus is likewise very short and but little curved, and is not divisible into anterior and posterior portions. The sylvian fissure itself is but feebly marked upon the cast, but the rhinal sulcus, on the contrary, is very distinctly shown and extends for nearly the whole length of the hemisphere. Making all due allowance for the fact that a cast of the brain-case can but imperfectly reproduce the features of the brain itself, yet it is clear that the cerebrum of *Cynodictis* was convoluted in a much simpler way than in any of the existing *Canidæ*, and that it retains characteristics which among the modern dogs are embryonic and transitory.

The *cerebellum* is rather large and is less overlapped by the hemispheres than is the case among the recent members of the family. The vermis is narrow, but prominent, and is quite clearly divisible into three lobes, corresponding apparently to the lobus centralis, lobus monticuli and declivus of *Canis*. The vermis is less regularly curved in the antero-posterior direction than in the modern genus, the posterior surface forming nearly a right angle with the dorsal. The lateral lobes of the cerebellum have quite a different appearance from those of the recent *Canidæ*. Thus, the lobus quadrangularis is less extended transversely and narrows less toward the external side, while the lobus lunatus inferior is very imperfectly developed, and the lobi semilunares appear not to be represented at all, or, if present, they must be exceedingly small. This latter point is difficult to decide definitely, because a small fragment of the skull, which cannot be removed without danger to the specimen, covers the place where the semilunar would be if present. A small additional lobe, not represented in *Canis*, lies upon the dorsal surface of the lobus quadratus and near to the vermis. Complex as it looks, the cerebellum of *Cynodictis* is simpler than in the recent dogs.

Measurements.

	No. 10513.
Brain, length fr. cerebellum to olfactory lobe (incl.).....	0.045
Olfactory lobe, fore and aft diameter.....	.005
“ “ vertical diameter.....	.011
Cerebrum, length in median line.....	.030
“ height at temporo-sphenoidal lobe.....	.025
“ width “ “ “ “ .....	.030
Cerebellum, length in median line.....	.013
“ width .....	.024
“ vertical height .....	.018
Medulla oblongata, width.....	.012

IV. THE VERTEBRAL COLUMN.

The backbone is not preserved entire in any of the specimens, but by the aid of the more complete individuals from the John Day, the numbers of the various categories of vertebræ may be inferred.

The *atlas* (Pl. XIX, Fig. 13) is somewhat more canine in character than that of *Daphænus*, having a short and broad body and moderately developed transverse processes. The anterior cotyles are shallower and more depressed than in *Canis*; the neural arch is well extended in the antero-posterior direction and is quite smooth, without ridges or tubercles of any kind; it is very strongly convex, giving to the neural canal an almost circular shape. The inferior arch is very slender and has but a rudimentary hypapophysial tubercle. The posterior cotyles for the axis are somewhat more concave than in *Canis* and present more obliquely toward the median line. The transverse processes are rather small and are much less extended antero-posteriorly than in *Canis*, not reaching so far behind the surfaces for the axis, nor so far forward upon the neural arch; in consequence of this, the atlanteo-diapophysial notch is less deeply incised. The posterior opening of the vertebrarterial canal presents backward, as it does in *Daphænus*, but has shifted a little more toward the dorsal side of the transverse process, thus showing a tendency to assume the position which is characteristic of the recent *Canidæ*.

The *axis* is not especially canine in appearance, but rather resembles that of *Viverra*. The centrum is long, narrow and very much depressed anteriorly, becoming somewhat deeper vertically toward the hinder end, which has a transversely oval and nearly flat face for the third vertebra; the ventral keel is relatively better developed than in *Daphænus*. The articular surfaces for the atlas are low and wide, but project much less outside of the pedicels of the neural arch than they do in *Canis*, and are more convex than in that genus. The odontoid process is slender and elongate, more so than in *Viverra*, and the articular surface on its ventral side is not, as in *Canis*, continuous with the lateral facets for the atlas, but is separated from them by a feebly marked ridge. The transverse processes, which are very thin and compressed, are of no great length; they are perforated by the vertebrarterial canal, which is relatively longer than in the recent dogs. The pedicels of the neural arch are short from before backward, but are quite high, and the neural canal is proportionately much larger in both dimensions than in the existing dogs. The neural spine, at least in the White River species, resembles that of *Daphænus* much less than it does that of *Canis*. It is long, not very high, and in front extends far in advance of the pedicels, but posteriorly it does not project behind the zygapophyses, as it does so conspicuously in *Daphænus*; as in the modern genus, the dorsal border of the spine is continued into the hinder margins of the neural arch. The zygapophyses are rather small and do not extend out so prominently from the sides of the neural arch as in *Canis*.

The axis of the John Day species, *C. geismarianus*, as figured by Cope ('85, Pl. LXXa, Fig. 12), differs from that of *C. gregarius* in having a much higher neural spine, which is continued posteriorly into a pointed projection, similar to but shorter than that seen in *Daphænus*.

The *third cervical vertebra* is markedly different from that of *Daphænus* and quite like the corresponding vertebra of *Canis*. The centrum is moderately elongate (though shorter with reference to the axis than in most of the modern dogs), quite depressed and slightly opisthocelous, and has a stout, prominent ventral keel, which is better developed than in *Daphænus*, or even than in *Canis*, and ends behind in a tubercle. The anterior face is broad, depressed, quite convex and very oblique in position with reference to the fore-and-aft axis of the centrum, while the posterior face is more nearly circular in outline. The transverse process is, in general character, quite like that of *Canis*, but has a relatively smaller extension from before backward, and is less obviously divided into anterior and posterior projections, the ventral margin of the process being nearly straight. The vertebrarterial canal is proportionately much longer than in *Canis*, being nearly as long as the entire centrum. The neural canal is relatively larger and especially wider than in the modern genus, while the neural arch is long and broad and but slightly convex on the dorsal surface. One noteworthy difference from *Canis* consists in the fact that the arch does not project over the sides, or pedicels, as an overhanging shelf, or does so but slightly. The neural spine is represented only by an inconspicuous ridge.

The zygapophyses are small and extend but little in front of and behind the neural arch, which constitutes a very marked difference from *Daphænus*. In the latter, it will be remembered, the neural arches are deeply emarginated between each transverse pair of zygapophyses, so that when the vertebræ are placed in their natural position, large vacuities occur between the successive neural arches. In *Cynodictis*, as in *Canis*, these interspaces are very narrow and in certain parts of the neck they are hardly at all visible.

The *fourth vertebra* is somewhat shorter than the third, but is otherwise very much like it and also like the corresponding vertebra of *Canis*. The transverse process is somewhat larger and heavier than on the preceding vertebra, and the greater antero-posterior extension of its outer portion makes the vertebrarterial canal relatively longer than in *Canis*; the inferior lamella is very thin and light. The neural spine is short and slender, but is relatively better developed than in most of the modern representatives of the family.

On the *fifth cervical* the neural spine is higher but more slender than on the fourth. The *sixth* is not preserved in connection with any of the specimens.

The *seventh cervical* is almost a miniature copy of the same vertebra in *Canis*; the neural spine is relatively higher, more slender and more pointed than in most species of the existing genus, and the transverse processes are proportionately longer and thinner, but otherwise the resemblance is very close and detailed.

The number of *thoracic vertebræ* cannot, as yet, be definitely stated, because in

none of the specimens is the series preserved entire. Probably, however, these vertebræ numbered thirteen, as is commonly the case among the recent representatives of the family. The specimen of *C. geismarianus* figured by Cope ('85, Pl. LXXa) has the posterior ten thoracics in place, and there must have been at least three additional ones. The anterior vertebræ of this region have very small, contracted centra, but long and prominent transverse processes and neural spines which are relatively higher and more slender than in *Canis*, and are also inclined more strongly backward than in the latter. Posteriorly the centra become longer, broader and more depressed, and are quite distinctly keeled in the median ventral line. In addition to this median keel are two shorter and less prominent lateral ridges, which, however, terminate behind in distinct tubercles and thus give a very characteristic appearance to these vertebræ. The transverse processes become more and more shortened and the neural spines lower, less strongly inclined, but more compressed and broadened at the base (antero-posteriorly). The antepenultimate thoracic (presumably the eleventh) is the anticiinal vertebra, of which the neural spine is low, broad, compressed and erect. The penultimate (? twelfth) and last (? thirteenth) thoracics are very much like lumbar in appearance and structure, but have no transverse processes, while in *Canis* these processes, though small, are quite distinct on the twelfth and thirteenth thoracics. Large, heavy and prominent anapophyses and metapophyses are present on the last two thoracics.

Of *lumbar vertebræ* this genus probably possessed seven, that many being preserved in position and in connection both with the thoracics and with the sacrum in Cope's specimen of *C. geismarianus*. In the White River material at my command not more than five lumbar have been found in association with any one individual, but the series is obviously incomplete, and there is no reason to suppose that *C. gregarius* differed in this respect from the John Day species. The lumbar region is proportionately long and stout and the individual vertebræ are quite massively constructed (*i. e.* for so small an animal), indicating a powerful musculature in this region. The centra increase in length up to that of the penultimate vertebra, while the first and the last are the shortest of the series. These centra are broad and depressed, and bear distinct median ventral keels, while the lateral ridges and tubercles are present on the first two vertebræ, but not on the last three. The faces are kidney-shaped, slightly convex in front and concave behind, and are placed obliquely with reference to the long axis of the centra. This obliquity is to provide for the curvature of the loins, which rise to the pelvis, the rump standing considerably higher than the shoulders. The transverse processes, which are quite short on the anterior lumbar, increase steadily in length up to the sixth, where they become very long; they are slender, depressed, pointed and curved forward. The neural spines are low, compressed and thin, broad at the base, narrow and pointed at

the tip, and are inclined forward rather more decidedly than in *Canis*. Anapophyses are quite prominent on the anterior lumbar, but diminish posteriorly, becoming rudimentary on the fifth, while the metapophyses are conspicuous in all. The zygapophyses are but moderately concave and convex respectively. The general aspect of the lumbar region is not canine in character, but rather resembles that of the civets and mustelines.

The *sacrum* is quite short and consists of three vertebræ, only the first of which has a contact with the ilium. The first sacral has a broad and much depressed centrum and large, expanded pleurapophyses, which give considerable width to the vertebra. The neural spine is a mere feebly marked ridge, while the spines of the second and third are higher and separate. The transverse processes of all the sacrals are fused into a continuous lateral ridge, but that of the third vertebra extends outward much farther than the others and ends in a point, an arrangement which gives to this sacrum an appearance quite different from that of *Canis*. The prezygapophyses of the first vertebra are large and conspicuous, but all the other zygapophyses of the sacrum are small. The neural foramina are remarkably small. The centrum of the last vertebra is almost as large as that of the first and the widely extended transverse processes make the sacrum nearly as broad behind as it is in front.

The *caudal vertebræ* are not preserved entire in any of the specimens, nor, indeed, can all of them be recovered from all the individuals combined, so that the number of tail vertebræ is, as yet, conjectural. However, enough remains to show the character of the tail and of the various elements which compose it. The tail was evidently very well developed, being relatively longer and stouter than in any of the recent *Canidæ*, and much like that of some of the long-tailed viverrines, such as *Herpestes*. The anterior caudal vertebræ have short, but heavy centra and very long, broad and depressed transverse processes, which extend out nearly at right angles with the line of the centrum. The breadth of the first caudal across the transverse processes about equals that of the last sacral. The zygapophyses of the anterior caudals are large and prominent. The anterior caudals are succeeded by a number of vertebræ with very elongate centra, which resemble in miniature the corresponding vertebræ of *Daphænus*, having distinct remnants of the various processes. Toward the tip of the tail the vertebræ become very slender and of a cylindrical shape, the centra being slightly contracted in the middle and expanded at the ends.

The *ribs*, so far as they are preserved in the various specimens, are remarkable chiefly for their length and slenderness and for their subcylindrical shape. Tubercles appear to be absent from the twelfth and thirteenth pair. The sternum is of the usual carnivorous character, without being especially like that either of the dogs or of the

civets. The manubrium is long, more so than in *Canis*, as well as narrower and more compressed. The first pair of ribs is attached to a pair of wing-like processes, which are unusually far from the second pair. In front of these processes the bone is compressed and very narrow. For much of its length the manubrium possesses a ventral keel. The segments of the mesosternum, so far as they are preserved in the various specimens, are more elongate, more slender and depressed and more contracted in the middle than in the recent *Canidæ*.

Measurements.

	No. 10493.	No. 11012.	No. 11381.	No. 11382.	No. 11432.
Atlas, length.....	.016				
" breadth.....	.034				
Axis, length (excl. of odontoid) .....	.019		.020		
" " of odontoid process.....	.005				
" breadth of anterior face.....	.013		.0135		
Third cervical, length.....	.011	.013	.012		.013
Fourth " " .....					.014
Fifth " " .....					.013
Sixth " " .....			.013		.012
Seventh " " .....			.011		.010
Anterior thoracic, length .....		.008	.009		.0085
Last thoracic, length .....	.012	.012	.013		
First lumbar, " .....			.015	.013	
Second " " .....			.017	.0145	
Fifth " " .....		.016	.018	.016	
" " width post. face .....		.010	.011	.009	
Sixth " length.....		.015	.017	.014	
Seventh " " .....			.013	.013	.012
Sacrum, length .....		.024	.026		
First sacral, width across pleurap.....		.024	.024		
Third " " " transv. pr .....		.021			
First caudal, length .....		.007	.008	.010	
" " width across transv. pr.....		.021	.026		
Median caudal, length					
" " width ant. face .....		.005			

V. THE FORE LIMB.

The *scapula* is quite remarkable and is in character rather viverrine or raccoon-like than canine. The shoulder blade is rather low and broad and is divided by the spine into pre- and postscapular fossæ of nearly equal breadth, while in the modern dogs the scapula is high, narrow and of subquadrate shape, and has the spine so placed as to make the postscapular fossa much the larger of the two. The glenoid cavity is moderately concave, and is elongate antero-posteriorly, but narrow transversely. The coracoid

process is unusually large, forming an incurved hook, which, however, does not appear prominently when the scapula is viewed from the external side; in the recent *Canidæ* the coracoid is reduced to much smaller proportions. A resemblance to the shoulder-blade of *Canis* is to be found in the broad neck of the scapula and in the absence of any well-defined coraco-scapular notch. The coracoid border is slightly concave at the neck, but then curves forward and upward, giving great width to the prescapular fossa; the glenoid border is, as usual, straight and is steeply inclined, so that the postscapular fossa, which is very narrow distally, becomes very broad proximally. The spine is high and ends in a very long and prominent acromion, which descends below the level of the glenoid cavity, which suggests that in this genus the clavicles were much better developed than in the existing dogs. A very large metacromial process is also present. The metacromion may be observed in most of the existing families of Carnivora, but it is seldom so large and so prominent as in *Cynodictis*; perhaps, the nearest approach to it among modern genera is in *Arctictis*.

The *humerus* is much more suggestive of viverrine than of canine affinities. As compared with the bones of the forearm, or even with the femur, the humerus is elongate, but it is short in proportion to the length of the back or loins. The head is strongly convex and projects farther behind the plane of the shaft than in the modern dogs; the external tuberosity is a heavy, but low ridge, which barely conceals the head when the bone is viewed from the front; a large, irregularly circular area near the hinder end of this ridge plainly indicates the insertion of the infraspinatus muscle. The external tuberosity is both lower and shorter than in the modern dogs, but the internal one is rather more prominent, and the bicapital groove is more widely open, more internal in position and more of it is visible from the anterior side. The shaft is rather long, and, when seen from the side, exhibits a sigmoid curvature, which is somewhat better marked than in *Canis*. For most of its length, the shaft is laterally compressed and has but a very short cylindrical portion before expanding laterally at the distal end. Most of the ridges and prominences for muscular attachment are well developed, more so than would be expected in so small an animal. The deltoid ridge is much more prominent than in the recent dogs, and is more like that of the cats and viverrines; the supinator ridge is likewise very much more prominent than in *Canis*, in correlation with the power of rotation of the radius, which *Cynodictis* appears to have retained in almost undiminished degree. On the other hand, the rough ridge, which runs down from the head upon the outer side of the shaft (*spina humeri*) and serves for the attachment of the *teres minor*, *anconæus externus* and *brachialis internus* muscles, is much fainter than in *Canis* and the *linea tuberculi minoris* is very feebly marked. The supratrochlear fossa is very shallow and the anconeal fossa is much smaller and shallower than in the modern representatives of the family, there being no perforation of the shaft

at this point. The internal epicondyle is much more prominent and more massive than in *Canis*, and a conspicuous epicondylar foramen is present, in the form of a long, narrow slit. The external epicondyle, on the contrary, is rather smaller than in the recent genus.

The humeral *trochlea* has a much smaller proximo-distal diameter than in the existing *Canidæ*, in which respect it preserves a primitive character and resembles the trochlea of such viverrine genera as *Cynogale* and *Viverra*. The radial surface is small and simply convex, while the ulnar facet is much larger than in the recent dogs; the inner flange of the ulnar facet is also more produced distally and forms a sharper edge than in the latter.

The *radius* is not at all suggestive of canine affinities, but rather resembles the corresponding bone of the cats and viverrines. The capitellum is small and of subdiscoidal shape; while it is somewhat more extended transversely than in *Felis*, it is much less so than in *Canis*; its articular surface is moderately concave and is slightly notched on the anterior border. The proximal facet for the ulna is a simple, convex band, separated from the humeral surface by a distinct angle and entirely resembling that of *Daphænus*. The character of the articulation at the elbow-joint and the large development of the supinator ridge on the humerus would seem to imply that in *Cynodictis* a considerable degree of freedom in the rotation of the manus had been preserved, though probably less than in the cats and in many viverrines. The bicipital tubercle is prominent, but occupies a more posterior position than in either the cats or the recent dogs, and is not visible when the radius is looked at from the front.

The shaft of the radius is relatively short, slender and rounded, very different from the broad, oval and antero-posteriorly compressed shaft seen in *Canis*; it has a slight double curvature, arching anteriorly and externally, and is of almost uniform thickness throughout its length, except at the distal end, where it broadens considerably. A very striking difference from *Canis* consists in the very great size and prominence of the styloid process, which forms a relatively enormous tuberosity; it is even much larger proportionately than in the cats or civets and is as large as in *Mellivora*, though of a different shape. In *Daphænus*, as we have already learned, the styloid process is very prominent and of a generally feline appearance, but it is proportionately smaller than in *Cynodictis*. The radius figured by Schlosser ('89, Taf. VII, Fig. 8) and by him attributed to one of the European species of the latter genus has a styloid process in the form of an enormous, recurved hook, much longer and much more slender than in the American species and of an entirely different appearance. The distal tendinal sulci are not very well marked, though that for the abductor and extensor muscles of the pollex is a deep groove. The distal facet for the ulna is smaller and less deeply impressed than in *Canis*. The carpal facet is small and slightly concave, narrowing toward the internal side; it

does not extend over upon the styloid process, from which it is separated by a broad and deep notch.

The *ulna* is, in its way, as peculiar as the radius. The olecranon is quite typically fissipede in character and differs from that of the creodonts in its comparative shortness and breadth; though proportionately somewhat longer than in *Canis*, it is hardly so long as in *Daphænus*, and the sulcus for the tendons of the anconeal muscles is more distinct than in the former. The sigmoid notch is hardly so deep as in *Canis*, and, in particular, the internal facet for the humerus projects less in front of the plane of the shaft, and the external process is very feebly developed. The radial facet is narrower and less deeply concave than in the modern *Canidæ*, but has a somewhat greater vertical diameter.

The shaft of the ulna is decidedly less reduced than in the recent representatives of the family, and for most of its length is little or not at all more slender than that of the radius. In its proximal portion the shaft is much more compressed laterally and thicker antero-posteriorly than in *Canis*, in which genus this portion of the shaft is trihedral. The middle and distal portions are of triangular section, none of it having the subcylindrical shape which characterizes the distal one-third of the shaft in the recent genus. The distal end has quite a different shape from that seen in *Daphænus*, a difference which is due to the much greater prominence of the radial facet in the latter. In *Cynodictis* this facet is almost sessile and projects but little more than it does in *Canis*. The carpal facet is very small and quite simply convex.

Measurements.

	No. 10493.	No. 11012.	No. 11381.	No. 11382.	No. 11432.
Scapula, length		0.054			
“ greatest width		2.049			
“ width of neck .....			.013		
“ ant. post.-diameter of glenoid cavity .....			.012	.0095	.0095
“ transverse “ “ “ .....			.008	.007	.007
Humerus, length .....		.075		.070	.070
“ ant. post. diam. prox. end .....	.012	.015	.019	.015	.015
“ transv. “ “ “ .....		.014	.016	.013	.0125
“ breadth of distal end .....		.016	.020	.015	
“ “ “ trochlea .....		.012	.0145	.011	
Radius, length .....	.057	.061			
“ ant post. diam. prox. end .....	.005	.006	.007	.005	.005
“ transv. “ “ “ .....	.007	.007	.009	.007	.007
“ breadth of distal end .....	.012	.013	.013		.009
“ “ “ carpal facet .....	.0055	.006	.007		.0055
Ulna, length .....		.072			
“ “ of olecranon .....		.007	.010	.0095	.009
“ thickness of olecranon .....			.010	.008	.008

VI. THE MANUS (Pl. XX, Fig. 23).

By a fortunate discovery of Mr. Hatcher's, I am enabled to give an account of an almost complete carpus belonging to *Cynodictis*, which has hitherto been entirely unknown.

A *scapho-lunar* is present, formed by the coalescence of the scaphoid, lunar and central, which distinguishes *Cynodictis* from the creodonts. This bone resembles that of *Canis* in general character, but displays quite a number of differences in points of detail, and these differences are, at the same time, approximations to the structure found in *Daphænus*. The scapho-lunar has a very small vertical (proximo-distal) diameter, especially on the radial side, where it thins away to a mere edge, the facets for the radius and the trapezium almost meeting. As compared with the corresponding carpal of *Canis*, this bone has a somewhat greater transverse and smaller dorso-palmar diameter. The radial facet is simply convex both transversely and antero-posteriorly, and has not the saddle-shaped extension at the interno-palmar angle which is found in the recent dogs. This facet descends quite low upon the dorsal side of the bone, as is also the case in the modern plantigrade and semiplantigrade carnivores. The hook-like process which arises from the postero-internal angle of the scapho-lunar is much shorter and less massive in every dimension than that of *Canis*. Another difference from the modern genus consists in the absence of any distinct articular surface for the pyramidal, the facet for the radius and that for the unciform almost coming into contact along the ulnar side of the bone.

On the distal side of the scapho-lunar are four facets, for all the carpal elements of the distal row. That for the unciform is relatively smaller than in *Canis*, and is confined to a narrow strip near the ulnar border; the magnum facet is much the same as in the modern genus, but is somewhat more oblique in position. The surface for the trapezoid is fairly large and keeps more nearly parallel with that for the magnum than in the recent dogs, while the trapezium facet is small and of almost circular shape.

The *pyramidal* is a very different-looking bone from that of the modern dogs, being broad, depressed and scale-like in shape; its vertical (or proximo-distal) diameter is very small and relatively much less than in *Canis*, and there is no such process from the ulnar side of the bone as in the latter, in which the pyramidal articulates with the head of the fifth metacarpal by a much more extensive facet than in *Cynodictis*. The recent viverrines have the pyramidal shaped very much as in the White River genus. The proximal surface is divided into two narrow and somewhat concave facets for the ulna and pisiform respectively, of which the latter is slightly the larger. On the distal side is a single large and concave facet for the unciform, and posterior to this

a very narrow surface which appears to be destined for articulation with the head of the fifth metacarpal.

The *pisiform* differs very decidedly in shape from that of *Canis*. This carpal is small and light; its proximal (*i. e.*, articular) end is greatly depressed, but much extended transversely (in the existing genus the principal diameter of the proximal end is the vertical one) and the facets for the pyramidal and ulna are correspondingly broadened transversely and narrowed vertically. The pyramidal facet is the larger of the two and is quite deeply concave, while that for the ulna is small and nearly plane; the two facets together form an acute angle and are separated only by an inconspicuous ridge. The distal end of the pisiform is moderately expanded, but in the vertical dimension, so that the proximal and distal expansions are almost at right angles with each other. Between the two expansions the body of the bone is much contracted and very slender, which is in marked contrast to the shape seen in *Canis*.

A so-called "*radial sesamoid*" appears to have been present; at least, there occurs in the same block of matrix through which the carpals of one individual were scattered, a small, irregularly wedge-shaped bone, to which I can give no other interpretation. Assuming that this reference is correct, we find in the relative size and shape of this bone another resemblance to such viverrine genera as *Herpestes*, *Cynogale* and *Paradoxurus*, etc. The radial sesamoid also occurs in *Canis*, at least in certain species, but is very minute.

The *trapezium* is very small and differently shaped from that of *Canis*; its principal dimension is the dorso-palmar, while the transverse diameter is the least. The surface for the scaphoid, which in *Canis* is a very oblique, convex facet, is in *Cynodictis* entirely proximal in position and nearly plane, and there is no such large concave facet for the trapezoid on the ulnar side as in the modern genus; the distal facet for the head of the first metacarpal is less distinctively saddle-shaped than in the latter. In view of the well-developed pollex, the small size of the trapezium is somewhat surprising.

The *trapezoid* is shaped very much as in the existing dogs, but with certain minor differences, especially noticeable in the very small vertical diameter and in the thinning of the bone to an edge on the ulnar side. The proximal end bears a simply convex facet for the scapho-lunar, while the distal facet, for the second metacarpal, is very slightly saddle-shaped; on the palmar side the trapezoid contracts to a point.

The *magnum* is small and that portion of it which is visible from the dorsal side, when all the carpal elements are in their natural positions, is minute, especially in its proximo-distal dimension. In shape the magnum does not differ materially from that of the recent dogs, but the proximal surface is narrower and rises more abruptly to the "head," and on the palmar side the bone broadens out in a fashion not repeated in *Canis*.

The unciform facet is large and plane and does not rise so high upon the head as in the modern genus. On the radial side we find no distinct facet for the trapezoid, which, as already mentioned, thins to a mere edge toward the magnum, but there is a well-defined facet for the projection from the head of the second metacarpal, which is proportionately larger than in *Canis*. On the distal end of the magnum is a narrow facet for the third metacarpal, a facet which is less concave in the dorso-palmar direction than in the case of the last-named genus.

The *unciform* is viverrine rather than canine in character, being much narrower in proportion to its vertical height than in the recent dogs. The facet for the scapholunar, which in *Canis* has an almost entirely proximal position, is in *Cynodictis* much more nearly lateral. The pyramidal facet is also decidedly more steeply inclined than in the existing genus, the two articular surfaces meeting at a very acute angle and making the proximal end of the unciform narrow and wedge-shaped. On the radial side is a large facet for the magnum and a small one, confluent with it, for the extension from the head of the third metacarpal. The distal facets, for the fourth and fifth metacarpals respectively, are narrower than in *Canis*, contracting especially toward the palmar side.

The *metacarpals*, five in number, are remarkably short, slender and weak and have but little resemblance to those of the recent dogs.

The *first metacarpal* is very small, but is, nevertheless, proportionately much less reduced than in *Canis*, taking the length of mc iii in each genus as a standard of comparison. The head is thicker and relatively heavier than in *Canis* and on the radial side, internal to the trapezium facet, is a tubercle for the attachment of the lateral ligament. The facet itself is much less deeply concave transversely than in *Canis*, but more convex in the dorso-palmar direction. The shaft is short, slender, arched toward the dorsal side, antero-posteriorly compressed and of oval section, tapering considerably toward the distal end. The distal trochlea is very small, but formed entirely like those of the other metacarpals; it is strongly convex, almost hemispherical and bears a distinct carina upon the palmar face, just as in *Daphænus*. In *Canis*, on the other hand, this structure is of an entirely different character, forming an asymmetrical hemicylinder, with a broad shallow groove placed somewhat internal to the median line, and thus resembles the trochlea of a phalanx rather than that of the other metacarpals.

The *second metacarpal* is represented in the collection only by a single imperfect specimen, consisting of the proximal end. This shows a much stouter shaft than mc i, being of about the same diameter as the corresponding portion of mc iv, and more slender than that of mc iii. The head is narrow and bears a saddle-shaped facet for the trapezoid, but sends out a projection which rises more above the head of mc iii than in *Canis* and articulates with the magnum by a larger facet than in that genus.

The *third metacarpal*, though short and slender, is somewhat the longest and heaviest of the series. The proximal articular surface for the magnum is shaped very much as in *Canis*, but is slightly broader in proportion and rather more concave transversely; on the radial side of the head is a large facet for mc ii, which has a more oblique position than in the modern genus. On the ulnar side is a small projection which abuts against the unciform and is relatively larger than in *Canis*. The shaft, and indeed the whole metacarpal, has a viverrine rather than a canine appearance; it has not acquired the prismatic, quadrate shape which is so characteristic of the modern dogs, but is of oval section and is of almost uniform width throughout, but broadens slightly at the distal end. The distal trochlea, though much lower in the vertical diameter, is yet of decidedly more canine character than is that of *Daphænus*, being broad and hemicylindrical in shape instead of subspherical. The pit above the trochlea, which is absent in *Daphænus*, is distinctly marked and the lateral processes for ligamentous attachment are much less prominent. All of these conditions are approximations to the conditions seen in *Canis*.

The *fourth metacarpal* is not completely preserved in any of the specimens, but it appears to have been of about the same length as mc iii and to have formed with it a symmetrical pair, although the two metacarpals are not so closely appressed as in *Canis*, but diverge slightly toward the distal end. The head has a simply convex facet for the unciform and is somewhat narrower proportionately than in the existing members of the *Canidæ*, owing to the overlapping of the head by mc iii, in order to reach the unciform. So far as it is preserved, the shaft is rather more slender than that of mc iii and of a more cylindrical, less compressed shape.

The *fifth metacarpal* is remarkably short, much more so in proportion to the length of mc iii than is that of *Canis*. The head is less broadened and thickened than in the latter genus, and carries a simple, convex facet for the unciform. In the modern genus there is likewise a large facet for the pyramidal, which extends down over the unciform and comes into contact with mc v. In *Cynodictis* there appears to be a facet of a similar kind, but if so, it is very small and obscurely marked and may be regarded as in only an incipient stage of development. The shaft is slender proximally and broadens distally, the reverse of the proportions which obtain in *Canis*, and the distal trochlea is small and is of somewhat more spherical, less cylindrical, shape than in the existing members of the family.

The *phalanges*. It is unfortunate that in all of the specimens in the collection the phalanges are in such a fragmentary state that only an incomplete account of them can be given, and some important questions must be left unanswered for the present. The proximal phalanx of one of the median digits is short, slender and straight, and is rela-

tively broader but more depressed than in *Canis*. As in *Daphænus*, the proximal articular surface is somewhat more deeply concave and presents more obliquely toward the dorsal side than in the recent genus. The distal trochlea likewise resembles that of *Daphænus* in having a deeper median groove and in being more confined to the palmar aspect of the bone than in *Canis*, which has the distal trochlea reflected well over upon the dorsal side of the phalanx.

Of the second phalanx only the proximal half is preserved in any of the specimens, and I have so far failed to find even a fragment of the distal end. So far as can be judged from the material at hand, *Cynodictis* would appear to have differed from *Daphænus* in the very important respect that the claws were not at all or only very imperfectly retractile. In *Daphænus* the asymmetry of the second phalanx is clearly displayed even in its proximal portion, while in *Cynodictis* the proximal end is quite symmetrical and does not possess any depression or excavation upon the ulnar side. However, a certain resemblance to *Daphænus* and difference from *Canis* may be observed in the greater concavity and more marked separation of the two pits into which the proximal facet is divided, as well as in the greater prominence of the beak-like process which rises from the dorsal margin and fits into the median distal groove of the first phalanx. In the absence of the distal end of the second phalanx, it cannot be positively stated that *Cynodictis* had lost (or had never possessed) all trace of the retractility of the claws, but it does not seem unlikely that such was the case.

Measurements.

	No. 10493.	No. 11012.
Carpus, height in median line		0.006
" breadth .....		.011
Metacarpal i, length .....		.012
" " width of proximal end .....	.0035	.004
" " " distal end .....		.003
Metacarpal ii, width of proximal end.....		.0035
Metacarpal iii, length.....	.022	.0215
" " width of proximal end.....	.004	.0035
" " " distal end.....	.005	.0045
Metacarpal iv, width of proximal end.....	.004	.0035
Metacarpal v, length .....	.017	.016
" " width of proximal end .....	.004	.004
" " " distal end.....	.004	.0045

The ungual phalanx differs in several not unimportant details both from that of *Daphænus* and that of *Canis*, and is, on the whole, intermediate in character between

the phalanges of the two genera. As compared with the ungual of *Daphænus*, it has a somewhat less concave proximal trochlea, a smaller subungual process, and a much less extensive bony hood reflected over the base of the claw. Indeed, this hood is rudimentary and can hardly be said to exist at all. The phalanx is also slightly thicker and has more convex faces. Comparing this ungual with that of *Canis*, we find it to be decidedly sharper, narrower and more compressed and to have a more deeply concave trochlea. In the modern genus the bony hood is almost as well developed as in *Daphænus*.

VII. THE HIND LIMB.

The *pelvis* approximates more nearly to the modern canine type than does that of *Daphænus*, though still retaining a number of primitive characters. A conspicuous difference from the recent members of the family consists in the elongation of the post-acetabular portion of the pelvis, which in *Canis* is short, and in the consequent change of shape of the obturator foramina. The ilium is fairly elongate and in shape is rather more viverrine than canine; the peduncle is short and laterally compressed, but of considerable dorso-ventral breadth. The anterior expansion of the ilium is less extensive than in *Canis*, in which genus the ilium widens gradually to the free end, or crista, while in *Cynodictis* it attains nearly its full width immediately in front of the peduncle, and from this point forward the dorsal and ventral (or ischial and acetabular) borders pursue an almost parallel course. The widening is almost confined to the ischial border, being very feebly marked on the acetabular border, and owing to this the shape of the ilium is much as in the modern *Herpestes*. The gluteal surface does not display the wide and simple concavity which is seen in *Canis*, but, as in *Daphænus* and *Dinictis*, there is a narrow dorsal depression and beneath this a convex ridge, but this ridge is not so prominent as in the other White River genera which have been mentioned. The iliac surface is short and narrow, and the sacral surface is small and placed far back, so that the ilium projects well in front of the sacrum. When viewed from above, the two ilia are seen to curve outward less, and to diverge less anteriorly than in the modern dogs. The acetabular border ends in a well-marked tubercle and the ilio-pectineal process is also quite prominent.

The ischium is relatively long and its anterior portion is slender, but posteriorly it expands into a broad plate. This posterior portion is much less decidedly everted and depressed and occupies a more vertical position than in *Canis*, and the ischial tuberosity, just as in *Daphænus*, is much more feebly developed than in the existing *Canidæ*. On the other hand, the spine of the ischium and the ischiadic notch are much more distinctly shown and are placed farther behind the acetabulum than in the latter, though not so far back as in *Herpestes*. The obturator foramen is narrower and more elongate than in

Canis, and its anterior border is notched by the obturator sulcus. The acetabulum is small, deep and nearly circular.

The anterior or descending ramus of the pubis is long and slender and encloses with its fellow a broad anterior pelvic opening. The horizontal ramus is proportionately longer and stouter and the symphysis is longer than in the recent dogs, almost as long as in the cats. The horizontal ramus is less flattened and depressed than in the former, forming a prominent ridge along the ventral side of the symphysis.

The *os penis* may be conveniently described in connection with the pelvis. In none of the White River specimens that have fallen under my observation is this bone preserved, but in the beautiful specimen of *C. geismarianus* figured by Cope ('85, Pl. LXX) it is present and in nearly its natural position, though Cope has omitted any mention of it in his description. Flower ('69) has pointed out the characteristics of this bone in the three sections into which he divides the fissipede carnivores. The Arctoidea "all have a large penis with a very considerable bone, which is usually more or less curved, somewhat compressed, not grooved, dilated posteriorly and often bifurcated or rather bilobed in front" (p. 14). The cats and viverrines "all have a comparatively small penis, with a more or less conical termination, and of which the bone is small, irregular in shape, or not unfrequently altogether wanting" (p. 22). To this statement *Cryptoprocta* forms an exception, having a bone relatively long, "slender, compressed, slightly curved, not grooved or divided anteriorly, rounded and slightly dilated at each end, but thickest posteriorly" (p. 23). In the hyænas the bone is wanting. The dogs resemble the raccoons, weasels, etc., in having a large os penis, "though the os is of a different form, being straight, wide, depressed and grooved" (p. 26). In *Cynodictis* this bone is entirely different from that of the modern *Canidæ*; it is long, slender, compressed laterally and strongly curved and is slightly grooved upon the sides, but not on the dorsal border; the anterior end is so broken that the presence or absence of a bilobation cannot be determined. The resemblance in the character of the os penis between *Cynodictis*, on the one hand, and *Cryptoprocta* and the mustelines, on the other, is an important fact, the significance of which will be discussed later.

The bones of the hind limb proper considerably exceed in length those of the fore limb; more so than in *Canis*, though the difference is rather between the proportions of the radius and tibia than between those of the humerus and femur.

The *femur* is slender and quite elongate and in essentials differs but little from that of *Canis*. The head is small, of hemispherical shape, and is set upon a somewhat longer and more distinct neck than in the modern genus, projecting more directly inward and less upward; the pit for the round ligament is deeply impressed but very small. The great trochanter is lower than in *Canis* and is separated from the head by a narrower,

shallower notch, while the digital fossa is relatively much smaller. The second trochanter occupies nearly the same position as in the modern genus, though somewhat more posterior, so that it is almost or entirely concealed when the femur is viewed from the front; it is of about the same prominence as in the existing dogs, but rather more slender and pointed. The intertrochanteric ridge, which connects the greater and the second trochanters, is rather better developed than in *Canis*, especially in the larger and longer-limbed individuals. What may fairly be regarded as a remnant of the third trochanter is present in the form of a low, short, thickened and rugose ridge, which is placed a short distance below the great trochanter. The third trochanter is all but universal among the Creodonta, and in rudimentary form it persists in many of the earlier and more primitive carnivores, such as *Dinictis*, but it is somewhat surprising to find it retained in so advanced a genus as *Cynodictis*. It is true that in certain muscular and powerful domestic breeds of dogs the third trochanter recurs, though it is not distinctly shown in the existing wild species of *Canidæ*.

The shaft of the femur is long, slender, arched strongly forward and slightly toward the internal or medial side. As would naturally be expected in so small an animal, the ridges for muscular attachment are not so prominent as in the modern species. On the anterior face no ridge for the vastus externus muscle is distinguishable and on the posterior face the linea aspera is neither so long nor so prominent as in *Canis*. The distal end of the femur has quite a different appearance from that seen in the existing members of the family; a difference which is principally due to the smaller size and less prominent projection of the condyles and rotular trochlea. The trochlea resembles that of the viverrines in being shallow and in having the two borders of nearly equal height and length, and also in the absence of any distinctly marked suprapatellar fossa. On the other hand, this trochlea is relatively narrower and extends farther up the shaft than in the civets. The condyles are small, of nearly equal size and prominence, and are separated by an intercondylar space which is relatively narrower than in *Canis*; small sesamoid bones were evidently, as in the existing species, attached to the proximal faces of the condyles.

The *patella* is viverrine, or more accurately herpestine, rather than canine in character. It is a short, rather wide, thin and scale-like bone, of subquadrate more than ovate shape. The articular surface for the femur, in correlation with the shallowness of the rotular groove, is but slightly concave proximo-distally, and even less convex transversely.

The *tibia*, as in *Canis*, is of about the same length as the femur. Compared with the radius, the tibia seems to be very long, but that this is due rather to the shortness of the radius than to the elongation of the tibia, appears from a comparison with the verte-

bral column, whence it becomes evident that all the limb bones of *Cynodictis* are proportionately shorter than those of *Canis*, and that the bones of the forearm are especially short. The tibia of *Cynodictis* differs from that of the modern canines in several particulars. The proximal condyles are of nearly equal size, but the external one projects much farther behind the plane of the shaft than in *Canis*, and on the distal face of the overhanging shelf thus formed is a facet for the head of the fibula, which is much larger and more distinct than in the recent genus. The tibial spine is bifid and very low, but the two parts are closely approximated, the condyles being less widely separated than in *Canis*. The cnemial crest, though stout and prominent, is much less so than in the modern forms, and the sulcus for the extensor longus digitorum is much less deeply incised. In its proximal portion the shaft is stout and trihedral, but for most of its length it is slender and subcylindrical, expanding moderately at the distal end; it has a double curvature, arching forward and outward. The various ridges which serve for the attachment of muscles are much the same as in *Canis* and are, consequently, better developed than those of the femur. The distal articular surfaces of the tibia are intermediate in character between those of *Daphænus* and those of *Canis*. The grooves for the astragalar condyles are deeper and the intercondylar ridge higher than in the former, less so than in the latter, and the sulcus which in *Canis* invades the articular surface has not yet been developed. The internal malleolus is somewhat smaller than in *Daphænus*, but, as in that genus, it forms a heavy, prominent ridge, which extends across the whole dorso-plantar diameter of the bone, while in *Canis* the process has not half this extension. The groove for the tendon of the long flexor muscle is very distinctly marked and has more elevated borders than in the modern dogs. The distal fibular facet is somewhat larger than that of *Canis* and differs from it in having its principal diameter transverse instead of longitudinal. The resemblance in the structure of the distal end of the tibia between *Cynodictis* and *Daphænus*, on the one hand, and the primitive sabre-tooth *Dinictis*, on the other, is very marked and very suggestive, though *Cynodictis* has already begun to change in the direction of the modern *Canidæ*. Among living forms the tibia of *Herpestes* offers a close analogy to that of the White River genera which have been mentioned.

The *fibula* is relatively much less reduced than in the existing *Canidæ*, and both the shaft and the terminations are larger. The proximal end of the fibula is much larger and heavier proportionately than in *Canis*, and though smaller than in *Dinictis*, it has a very similar shape; its principal diameter is the antero-posterior one, while transversely it is narrow and compressed; the thickening of the anterior and posterior border is present, as in *Dinictis*, but much less conspicuous. The facet for the head of the tibia is large, subcircular in shape and proximo-lateral in position. The shaft, though

slender and delicate, is relatively very much less so than in *Canis*, in which genus the fibula has undergone a more extensive reduction than in *Cynodictis*. Another difference from the recent forms is to be found in the fact that the fibula is not so closely applied to the tibia, the two bones coming into contact only at their proximal and distal extremities. The distal end is expanded and thickened to form a stout external malleolus, which is somewhat smaller than in *Daphænus* or *Dinictis*, but of much the same shape, and has on its outer side a deep sulcus for the peroneus tertius tendon. The distal tibial facet is a narrow band, with its long diameter directed antero-posteriorly; obscurely separated from it is the larger, subcircular facet for the astragalus.

Measurements.

	No. 10493.	No. 11012.	No. 11381.	No. 11382.	No. 11432.
Pelvis, length		20.064			
“ breadth at acetabulum .....		.036	.037		
Ilium, length fr. acetabulum.....		2.033	.037		
“ breadth of peduncle.....		.011	.010	.009	
“ “ “ ant. plate.....				.013	
Ischium, length fr. acetabulum.....		.027		.026	
Acetabulum, fore-and-aft diameter .....		.008	.011		
Femur, length.....			.096	.085	.086
“ breadth of prox. end .....		.017	.020	.015	.016
“ “ “ distal end.....		.016	.017	.014	.014
Tibia, length.....		.089	.099		
“ breadth of prox. end.....		.015	.018	.014	.014
“ thickness of prox. end .....		.013	.016	.012	.012
“ breadth of distal end.....	.009	.011	.012	.009	.009
Fibula, thickness of prox. end .....		.007			
“ “ “ distal end .....	.0065		.009		

VIII. THE PES (Pl. XX, Fig. 24).

The general appearance of the hind foot recalls that of the viverrines. The *astragalus* is quite like that of *Daphænus*, but with some differences which tend in the direction of the modern *Canidæ*, this bone in *Cynodictis* standing intermediate in structure between the two extremes, though somewhat nearer to *Daphænus*. The proximal or tibial trochlea is but little more deeply grooved than in the latter genus, and is therefore much shallower than in *Canis*, but its borders have the same clean-cut angularity as in the modern forms, instead of curving gradually into the facets for the tibial and fibular malleoli. In *Canis* the tibial trochlea is extended over upon the dorsal side of the neck, but this is not the case in either of the White River canines. The neck of the astraga-

lus is relatively longer than in *Canis* or even than in *Daphænus*, resembling that of such viverrine genera as *Paradoxurus*, but is not directed so strongly toward the tibial side of the foot as in *Daphænus*. The head with its convex navicular facet is shaped much as in *Canis*, except that it is more depressed in the dorso-plantar dimension. In *Daphænus* there is a distinct facet for the cuboid, which meets the navicular facet nearly at right angles; in *Cynodictis* this cuboidal facet is very much smaller and sometimes it is altogether wanting, while in *Canis* the astragalus and cuboid are not in contact. As in *Daphænus*, the external calcaneal facet is more oblique in position and more simply concave than in *Canis*, but the sustentacular facet is different from that of both the genera mentioned; it agrees with that of *Daphænus* in being shorter and wider than in the modern forms, but while in the former this facet is separate from that for the navicular, in *Cynodictis*, as in *Canis*, it is confluent with it, but at a different point; *i. e.*, more toward the tibial side. The interarticular sulcus is somewhat deeper than in *Daphænus*, but shallower than in *Canis*. In the latter we find a third calcaneal facet which forms a narrow band upon the fibulo-plantar side of the head and is connected at one end with the sustentacular facet. This accessory calcaneal facet does not occur in either of the White River genera.

The *calcaneum*, like the astragalus, is more viverrine than canine in general appearance and quite closely resembles that of *Paradoxurus*, but the resemblance to *Daphænus* is even more marked. The tuber is slender, compressed and proportionately much shorter than in *Canis*; in the latter the tuber makes up more than two-thirds of the total length of the calcaneum, while in *Cynodictis* it is about two-fifths of this length. The free end of the tuber is moderately thickened and club-shaped and is deeply grooved by the sulcus for the plantaris tendon. As in *Daphænus*, the dorsal and plantar borders of the tuber are nearly parallel and its dorso-plantar diameter is thus almost uniform throughout, not increasing toward the distal end as it does in *Canis*. Near the distal end of the calcaneum and on the fibular side is a very prominent process for the attachment of the lateral ligaments. This process is not present in the recent *Canidæ*, but is very conspicuous in the primitive carnivores, such as *Dinictis* and *Daphænus*, and it recurs among modern plantigrade and semiplantigrade forms, such as *Procyon*, *Gulo*, *Paradoxurus*, etc. Usually, however, it is smaller and less prominent in the fossil than in the recent genera. The facets for the astragalus are somewhat different from those of both *Daphænus* and *Canis*. In the latter the external astragalar facet is in two parts, one of which presents distally and the other dorsally, the two meeting at an angle which does not much exceed 90° ; in the former the whole facet forms one continuously curved convexity, not divided by an angulation. In *Cynodictis* the two parts are distinguishable as in *Canis*, but they meet at a much more open angle. The sustentaculum is of moderate

prominence and, as in *Daphænus*, it carries a subcircular facet for the astragalus ; in the modern genus this surface is narrower and more elongate. The sustentaculum also agrees with that of *Daphænus* in not being so obliquely placed, with reference to the long axis of the calcaneum, as in the existing members of the family. On the plantar side, between the sustentaculum and the body of the bone, is a groove, the sulcus flexoris hallucis, which is better marked in *Canis* than in either of the White River genera. This is curious, in view of the fact that the latter possess a well-developed and functional hallux, while in the former this digit is reduced to the merest rudiment. In *Canis* we find a third facet for the astragalus, a small plane surface distal to the sustentaculum, from which it is separated by a narrow sulcus ; continuous with this accessory facet, but at right angles to it, is a small facet for the navicular. Neither of these articular surfaces is to be found in *Cynodictis*. The facet for the cuboid, which in the recent dogs is almost plane and semicircular in shape, is quite deeply concave and of nearly circular outline.

The *cuboid* is relatively high and narrow, differing from that of *Canis* principally in the smallness of its transverse and dorso-plantar diameters. The proximal surface is occupied by a large facet for the calcaneum, which, as in *Daphænus*, is much more convex than in the existing dogs. The hook-like projection from the plantar side, which in *Daphænus* is very large and prominent and in *Canis* is even more massive, in the present genus is quite inconspicuous and is continuous with the projection from the fibular side which overhangs the deep tendinal sulcus. The astragalar facet is small and is confined to the dorsal side of the cuboid, being much less extensive than in *Daphænus*. The facet for the navicular is not so prominent as in *Canis* or even as in *Daphænus*, and is continuous with that for the ectocuneiform. The distal end of the cuboid resembles that of *Daphænus* in having quite a concave facet for the head of the fourth metatarsal, while that for the fifth is lateral in position. In *Canis*, on the other hand, the surface for mt. iv is almost plane and that for mt. v occupies an entirely distal position ; the plantar portion of the facet for mt. iv is much narrower than in the two White River genera, and has thus quite a different shape and appearance.

The *navicular* is almost a miniature copy of that of *Daphænus* and presents the same differences from that of *Canis*. Seen from the proximal end, it is of more regularly oval shape and is less contracted on the plantar side than in the modern genus. The position of the navicular in the tarsus is likewise different. In *Canis* this bone has been somewhat rotated, so that its principal diameter is the dorso-plantar one, and on the plantar border it has been brought into contact with the calcaneum, for which it has acquired a special facet. It is of interest to observe that a similar but more extensive rotation of the tarsal elements has been carried out in the horses, as Rüttimeyer has shown. In the White River genera, on the other hand, the principal diameter of the

navicular is transverse, and owing to the elongation of the neck of the astragalus, it is carried so far distally that it can have no contact with the calcaneum, the astragalus articulating with the cuboid. The astragalar surface is concave, but somewhat less so than in *Canis*, and the facet for the cuboid is small and confined to the dorsal moiety of the fibular side. The distal end displays the usual facets for the three cuneiforms, which do not require any particular description.

The *entocuneiform* has much the same shape as in *Canis*, elongate in the proximo-distal diameter, but very narrow and much compressed. The navicular facet is relatively smaller than in the modern genus and there is no such distinct facet for the mesocuneiform. The distal surface, for the head of the first metatarsal, is no wider but much more deeply concave than in *Canis*.

The *mesocuneiform* is a minute bone and, as in the fissipede Carnivora generally, its vertical or proximo-distal diameter is much less than that of the adjoining ento- and ectocuneiforms, forming a depression or recess in the distal row of the tarsus, into which the head of the second metatarsal is tightly wedged. The only articular surfaces visible on the mesocuneiform are the proximal and distal, for the navicular and the second metatarsal respectively.

The *ectocuneiform* is much the largest of the three. Compared with that of *Canis*, it is narrower in proportion to its height and is also less extended in the dorso-plantar dimension, but the projecting process from the plantar surface is even more prominent, and is more thickened and club-shaped at the free end. On the tibial side is a minute facet (not double as in *Canis*) for the side of mt. ii. The facet for the cuboid is much smaller than in the modern dogs and is confined to the dorsal border, while at the infero-external angle of the bone is a minute facet for the head of mt. iv, which is not represented in *Canis*. The distal end of the ectocuneiform is taken up by a facet for mt. iii, which is less concave and has a shorter plantar prolongation than in the modern genus.

The *metatarsus* consists of five well-developed members. Unfortunately, there is not a single complete metatarsal preserved in connection with any of the specimens, but enough remains to show that these bones were much longer and stouter than the metacarpals, and that the disproportion in size and length between the fore and hind feet was much greater than in the recent dogs and quite as great as in many viverrines, such as *Herpestes* and *Paradoxurus* or as in *Daphænus*.

The *first metatarsal* is sufficiently well preserved to indicate that the hallux was well developed and functional, though somewhat more reduced than in *Daphænus*, or in such recent viverrines as *Cynogale* or *Paradoxurus*. The head bears a narrow, convex facet for the entocuneiform and upon its tibial side is a large, rugose prominence for the attachment of the lateral ligament. The shaft is very slender and is arched slightly

toward the fibular side of the foot, making the tibial border somewhat concave. The length of the bone, as already intimated, is not determinable, but the portion preserved in one specimen is nearly as long as the entire fifth metacarpal of the same individual.

The *second metatarsal* is much stouter than the first and more slender than the third. The head is very narrow, being slightly excavated on the tibial side. Owing to the shortness of the mesocuneiform, the head of mt. ii rises above the level of mt. i and iii and is firmly held between the ento- and ectocuneiforms, though there are no such distinct lateral facets for these tarsals as we find in *Canis*; a stout prominence occupies the plantar side of the head. The shaft is slender and of oval section, not having acquired the trihedral shape characteristic of the recent dogs.

The *third metatarsal* is the stoutest of the series; the head is broad dorsally but very narrow on the plantar side, where there is a large, projecting process, more prominent than in *Canis*. The facet for the ectocuneiform is convex (in the recent dogs it is slightly concave) and oblique in position, inclining downward toward the tibial side. Deep sulci invade the head on both sides; on the tibial side the sulcus is narrow, but that on the fibular side is broad. A deep pit on the fibular side of the head receives a corresponding prominence from mt. iv, and an additional facet for the same metatarsal is found on the plantar projection, so that the two median metatarsals are very firmly interlocked. The shaft, for most of its length, is of transversely oval section, very different from the squared, prismatic shape seen in *Canis*, though an approximation to this shape occurs in the proximal portion of the shaft, where mt. iii and iv are closely appressed. The distal end is broadened and antero-posteriorly compressed; the trochlea resembles that of the corresponding metacarpal, save that it is larger and relatively somewhat lower.

The *fourth metatarsal* is of nearly the same thickness as mt. iii, though a trifle more slender. The head is narrow and the facet for the cuboid is slightly convex in both directions; the plantar extension is neither so broad nor so prominent as in *Canis*. On the tibial side is a rounded protuberance, which is received into the depression already mentioned, in the head of mt. iii, while on the fibular side is an excavation for a prominence on mt. v, and proximal to this excavation is a narrow but well-defined facet for the same metatarsal. Very little of the shaft is preserved, and this proximal portion has much the same tetrahedral shape as in the recent dogs. Doubtless, however, the distal part of the shaft assumes a transversely oval section, as does that of mt. iii, though the digits of the pes evidently diverge less distally than do those of the manus.

The *fifth metatarsal* is entirely missing from all of the specimens, so that the interesting question regarding the reduction of the external ascending process cannot be answered.

The *phalanges* of the pes do not differ from those of the fore foot, except in their considerably greater size.

Measurements.

	No. 10493.	No. 11012.	No. 11381.
Tarsus, height (excl. calcaneum).....	.021		
Calcaneum, length .....	.0195	.020	
" length of tuber .....	.012	.012	
" dorso-plant. diam.....	.007	.008	
Astragalus, length .....	.013	.013	.014
" width of trochlea .....	.005	.0055	.006
" length of neck.....	.006	.006	.006
" width of head .....	.007	.007	.008
Navicular, height .....	.003		
" width .....	.006		
Ectocuneiform, height.....	.0045		
" width dist. end .....	.0045		
Metatarsal i, width prox. end .....	.0045		
" ii, " " " .....	.003	.003	
" iii, " " " .....	.005	.005	
" iii, width dist. end.....		.005	
" iv, width prox. end.....	.0035		

IX. RESTORATION.

The general appearance of the *Cynodictis* skeleton has little about it to suggest canine affinities, but has some resemblance to the civets and especially to the herpestine section of that family. This resemblance is not merely a general one of outline and proportions, but may also be traced in many of the details of structure. The small head, with its elongate and narrow cranium and short, tapering muzzle, is of strikingly viverrine character. So is also the neck, which is relatively long and stout, the vertebræ having heavy centra and well-developed processes. The resemblance to the civets continues into the thoracic region, where the vertebræ are small, especially in the anterior portion, and have short, slender neural spines. The thorax itself, with its slender and moderately curved ribs, is narrow and compressed, as in the Carnivora generally, while the prominent and compressed manubrium has a somewhat viverrine appearance. The lumbar region is long and is strongly curved upward; the vertebræ are much elongated, with stout depressed centra, very long, slender and anteriorly directed neural spines, which are not like those of modern dogs or civets and most resemble the spines of *Lynx*. The transverse processes are likewise peculiar in their length and slenderness. The tail is unlike

that of the modern dogs, being much longer, stouter and in every way better developed; it was not, perhaps, quite so long proportionately as in *Herpestes*, but nearly so. This, however, is a primitive feature, which is common to the greater part of the earlier carnivores and ungulates, and is even more conspicuous in *Daphænus* than in *Cynodictis*, while the White River Machairodonts, *Dinictis* and *Hoplophonus*, have very long and massive tails.

The limbs, though not so long proportionately as in the recent dogs, are much more so than in the John Day species, *C. geismarianus*, the hind legs being especially elongate. The scapula is not at all canine in character, being relatively very large and having the broad blade and irregularly curved coracoid border of the viverrines; the great length of the acromion and the unusual size of the metacromion are peculiar. The humerus is short but quite heavy, and with its low trochlea, prominent deltoid and supinator ridges, and large epicondyle and epicondylar foramen, has an exceedingly viverrine appearance. The ulna and radius are relatively short and slender, and the discoidal head of the latter shows that the power of rotating the manus had been but little diminished; the great styloid process of the radius is very characteristic. The carpus is low and the metacarpals are exceedingly short and weak, resembling in their proportions those of *Paradoxurus*. The phalanges are elongate and the claws sharp and compressed.

The pelvis has a viverrine appearance in its shape and in the elongation of its posterior portion, while the os penis resembles that of the mustelines in size and curvature. The femur is long and the tibia is somewhat longer than the femur, bearing much the same relation to that bone as in *Canis*, while the fibula is much stouter than in the modern genus. The pes is far larger in all its dimensions than the manus, the difference in size between the two being much greater than in *Canis*. It is often exceedingly difficult to determine from the bones alone whether a given animal was plantigrade or digitigrade in gait, but from the resemblance of the limb and foot bones of *Cynodictis* to those of the civets, it seems very probable that the former had a similar semiplantigrade gait.

The John Day species, *C. geismarianus*, is considerably larger than the White River forms, but resembled the latter in proportions. Cope says of it: "Although the skull and pelvis of this species have about the size of those of the fisher, the vertebræ and humerus are more slender and the anterior foot is decidedly smaller. It is probable that the *Galecynus* [*i. e.*, *Cynodictis*] *geismarianus* resembled a large *Herpestes* in general proportions rather than a *Canis*. It stood lower on the legs than a fox and had as slender a body as the most 'vermiform' of the weasels, the elongation being most marked in the region posterior to the thorax. The tail was evidently as long as in the Ichneumons. Its carnivorous propensities were as well developed as in any of the species mentioned,

although, like all other *Canidæ* of the Lower Miocene period, the carnassial teeth are relatively smaller than in the recent types" ('85, p. 929).

The White River species of this genus are probably two in number.

CYNODICTIS GREGARIUS Cope.

Syn. *Amphicyon gracilis* Leidy (*non* Pomel), *Proc. Acad. Nat. Sci. Phila.*, 1856, p. 90 ; 1857, p. 90 ; *Ext. Mamm. Fauna Dak. and Nebr.*, p. 36. *Amphicyon angustidens* Marsh, *Amer. Journ. Sci. and Arts*, 3d Ser., Vol. II, p. 124. *Canis gregarius* Cope, *Ann. Rept. U. S. Geolog. Surv. Terrs.*, 1873, p. 506. *Galecynus gregarius* Cope, *Tertiary Vertebrata*, p. 916.

This is the species which has been described so minutely in the foregoing pages. It is one of the commonest White River animals and is very much more frequently met with than any of the contemporary carnivores. Despite this abundance of individuals, well-preserved specimens are rare and even these consist mostly of skulls only. As will be seen from the tables of measurements, the different specimens vary little in size or in the proportions of the various parts of the skeleton. One apparent exception to this statement may be found in the case of No. 11381, which is remarkable for the length of its hind limb, but this probably belongs to the following species :

CYNODICTIS LIPPINCOTTIANUS Cope.

Canis lippincottianus Cope, *Synopsis of Vertebrata Collected in Colorado ; Miscell. Publ. U. S. Geolog. Surv. Terrs.*, 1873, p. 9 ; *Ann. Rept. U. S. Geolog. Surv. Terrs.*, 1873, p. 506. *Galecynus lippincottianus* Cope, *Tert. Vert.*, p. 919.

The status of this species is still a matter of some uncertainty ; Cope, who established it upon mandibular rami, describes it as having "dimensions half as large again as in *C. gregarius*," and adds : "Unfortunately there is not enough material in my hands to render it clear whether the specimens represent a distinct species or a large variety of the *C. gregarius*" ('85, p. 920).

Among the specimens described in the foregoing pages is one (No. 11381) in which the limb bones decidedly exceed in length and thickness those of the other individuals, while the cranium is but little larger. Probably this specimen should be referred to *C. lippincottianus*, but in the absence of teeth the reference can be only provisional.

In the John Day formation *Cynodictis* is represented by more numerous and more varied species than in the White River beds ; from the former horizon Cope has determined *C. gregarius*, *C. lemur*, *C. latidens* and *C. geismarianus*.

Still another species should be mentioned in this connection. In the American Museum of Natural History, New York, are the remains of a small cynoid animal from the Uinta beds, which may belong to *Cynodictis*, or if not, should be referred to some closely allied genus. It is important to observe that in the Uinta stage (uppermost Eocene or lowest Oligocene) we find that the two canine series, represented in White River times by *Daphænus* and *Cynodictis*, had already been established.

THE PHYLOGENY OF THE CANIDÆ.

It seems probable that the fossil genera of this family already known are sufficient to indicate to us the main outlines of its phylogenetic history. The problem of reconstructing the series is, however, obscured by two circumstances; first, the variety and multiplicity of nearly allied genera, the mutual relationships of which are very complex and difficult to disentangle; and in the second place, by the fact that only rarely do we obtain satisfactory material of any of the genera. Most of the forms are known only from the skull and teeth, and the skeleton has, so far, been found in but few of the species. *Cynodictis*, *Daphænus*, *Temnocyon* and *Ælurodon* are now known from more or less complete skeletons, but we shall need to learn far more than we know at present concerning the structure of the other genera before we can reach a solution of the many problems of canine phylogeny.

Before taking up the discussion of these phylogenetic problems, it will be convenient to establish the order of geological succession in which the various genera make their appearance. We have seen that in the Uinta there appear to be two distinctly separated canine series, one of which is represented by ? *Miacis* and the other by a genus which is very closely allied to, if not identical with *Cynodictis*. The former series would seem to be continued into the White River by *Daphænus* and the latter, of course, by *Cynodictis*. The latter genus may well prove to be of Old World origin, for in the European Oligocene it attains such a variety and fullness of development as it never reached in America, although, on the other hand, the American creodont genus *Miacis*, from which *Cynodictis* probably took its origin, has not yet been found in Europe. In the John Day stage the canine phylum underwent an extraordinary expansion. *Daphænus* persisted, but is represented only by a single small species, *D. cuspidigerus*, while the series branched out into several distinct and more or less specialized genera, such as *Temnocyon*, *Hypotemnodon*, *Cynodesmus*, *Enhydrocyon*, and perhaps even the little known *Hyænocyon*. No new genera of the *Cynodictis* series have yet been detected, but that genus itself became differentiated into many more species than occur in the White River, and some of these may, on better knowledge, prove to be generically distinct. On the other hand, *Oligobunis* probably represents, as Schlosser has suggested, an immigrant

from the Old World, belonging to the series which leads from the Oligocene *Cephalogale* to the Pliocene *Simocyon*. The dogs of the Loup Fork, with the exception of the aberrant *Ælurodon*, are very imperfectly known and the remains of them which have been found are not, according to present knowledge, generically separable from *Canis*, though it hardly seems probable that the modern genus had actually been differentiated so early as the upper Miocene, and we may regard it as extremely likely that these supposed representatives of *Canis* will eventually prove to belong to more primitive genera. None of the forms which have hitherto been found in the Loup Fork beds can be referred to the *Cynodictis* line.

The mutual relationships between the two canine series, which are already so well distinguished in the Uinta, are quite obscure and puzzling, although there is nothing to forbid the assumption that both series converge to a common ancestor in the Bridger, perhaps the genus *Miacis*. The *Cynodictis* series, when we first meet with it, is decidedly more advanced than the other phylum, as is shown in the development of the skull, the reduction of the dentition, the character of the limbs and feet and the digitigrade gait. Continuing through the White River age and, so far as North America is concerned, attaining its maximum of development in the abundance and variety of its species in the John Day, the line apparently disappears and can be traced no farther. Whether the series actually died out at the end of the John Day, or whether it continued farther and possesses representatives even at the present time, are questions which cannot yet be definitely answered. Schlosser ('88, p. 247) has suggested that some of the species of *Cynodictis* may, perhaps, be of phylogenetic significance in the canine stem, but if so, they can hardly be placed in the thooid series, which apparently has no place for them. M. Boule ('89, p. 321), in an article upon the Pliocene *Canis megamastoides* Pomel, comes to the conclusion that the modern *Canidæ* are diphyletic, and have arisen by a process of convergence, the thooids and the bears being divergent groups derived from *Amphicyon*, while the alopecoids and viverrines are descended from *Cynodictis*. In discussing the affinities of the Pliocene form Boule says :

“ La description précédente nous montre que le fossile de Perrier se rattache de plus près aux Renards qu'aux autres représentants actuels de la famille des Canidés. Par son crâne, le *Canis megamastoides* ressemble beaucoup le Renard de nos pays. Par la forme de sa mandibule, il se place au contraire près des Renards américains (*Canis cancrivorus*, *C. azaræ*, *C. cinereoargentatus*) et près de l' *Otocyon megalotis* de l'Afrique australe. Ces espèces, notamment la dernière, sont regardées par tous les auteurs comme des formes primitives.

“ Tout en ratifiant ce premier rapprochement, la dentition présente des caractères particuliers que nous retrouvons en grande partie dans les *Cynodictis* et *Cephalogale* du Miocène (p. 327).

“ Les belles recherches de M. Filhol nous ont révélé la richesse en espèces de ces genres si curieux, placés aux confins de plusieurs familles de Carnassiers. Les *Cynodictis* et les *Cephalogale* avaient la formule dentaire des Chiens actuels, mais leurs dents présentaient un aspect particulier qui a valu à ces animaux fossiles le nom de *Chiens viverriens*. Or en étudiant les pièces originales de la collection du Muséum et les livres de M. Filhol sur les Phosporites du Quercy, j'ai été frappé de retrouver, comme parsemés dans diverses espèces de *Cynodictis* beaucoup des caractères présentés par le *Canis megamastoides* ” (p. 328).

“ Il semble donc que les Renards actuels représentent une branche émanée du buisson touffu des *Cynodictis*, duquel se serait également détachée la branche des Viverridés. Je suppose que lorsqu' on connaîtra suffisamment les membres des diverses espèces de *Cynodictis*, on trouvera des formes de passage allant d'un côté aux membres des Viverridés et d'un autre côté aux membres des Renards.

“ Si ces considérations sont exactes, les Chiens ont une origine différente des Renards. Les *Amphicyons* représentent les ancêtres communs des Ours et des Chiens, comme les *Cynodictis* représentent les ancêtres communs des Civettes et des Renards ” (p. 329).

M. Boule's argument as to the derivation of the foxes from *Cynodictis* is not a very convincing one and is open to several obvious objections. In the first place, M. Boule does not define the sense in which he uses the term *fox*; it is evidently not the same as Huxley's alopecoid, for *C. cancrivorus* and *C. azaræ* are called foxes, while Huxley regarded them as typical though primitive thooids. M. Boule does not say whether *C. megamastoides* possessed a frontal sinus, but from the statement that “ le frontal est saillant, à surface arrondie ” (pp. 324, 325), one would infer the presence of a sinus, and if so, *C. megamastoides* is not an alopecoid, but a thooid. The presence or absence of frontal sinuses and the shape of the cerebral fossa are the only diagnostic characters which Huxley could find definitely distinguishing the two canine series from each other. In the second place, the resemblances in tooth structure between *Cynodictis* and *Canis megamastoides*, upon which M. Boule places such emphasis, are in themselves of no great value, because the resemblance of the latter species to *Cephalogale* is even greater, and *Cephalogale*, as Schlosser has shown, probably belongs in a totally different line, which has no existing representatives. In any event, the gap between the Pliocene and Oligocene forms is still so wide that no determination of the taxonomic value of their resemblances and differences can yet be made.

Again, it is highly improbable that the viverrines can be descended from *Cynodictis*, for the latter, though having certain marked resemblances to the civets, is in all essentials of structure distinctly a member of the *Canidæ*, and is no more ancient than certain unmistakable viverrines. Indeed, the genus *Viverra* itself is reported from the

upper Eocene of Europe, occurring in the same horizons as those in which *Cynodictis* first appears. For similar reasons, it is very difficult to believe that *Amphicyon* can be the ancestor of the thooids, for that genus has already begun to become differentiated in the direction of the bears and is contemporary with or even younger than certain American genera, such as *Temnocyon* and *Cynodesmus*, which are undeniable thooids.

M. Boule's hypothesis involves some rather startling consequences; if true, we shall be forced to conclude that the two series of modern *Canidæ* have been separated ever since the close of Eocene times and that they had no common ancestor nearer than the middle Eocene or Bridger stage. This conclusion would imply such an extreme and remarkable degree of parallelism or convergence as has hardly been believed possible, an exact parallelism in all parts of the dentition, skeleton and soft parts, terminating in almost complete identity of structure. Indeed, many systematists regard most of the modern foxes and wolves as belonging to the single genus *Canis*, and Huxley speaks of the differences between them as being so slight, that a generic separation can be justified only on the grounds of convenience. Is it conceivable that two series of mammals which were already separated in the Eocene should have converged into what is practically a single genus?

Unlikely as it may appear, I am inclined to believe M. Boule's hypothesis concerning the relationship of *Cynodictis* to the alopecoids is not to be summarily dismissed, but that it may eventually prove to be well founded. It is certainly a suggestive fact that *Cynodictis*, like the foxes, is devoid of any frontal sinus, while all of the other American genera, from *Daphænus* onward, have well-marked sinuses, as in the wolves. Furthermore, whatever conclusion we may reach with regard to the single or dual origin of the *Canidæ*, there is much reason to believe that such extreme cases of parallelism and convergence have occurred among mammalian phyla and that they may be more frequent than is commonly supposed. One very striking example is that of the true cats (*Felineæ*) and the sabre-tooth series (*Machairodontinæ*) originally pointed out by Cope and elaborated in much detail by Adams ('96).

Unfortunately, complete demonstration is lacking in this very extraordinary case of parallel development, because the early stages in the phylogeny of the true cats have not yet been recovered, but the successive genera of the Machairodonts are fairly well known, and they form a connected series. None of these machairodont genera, not even the earliest and most primitive of them, can be regarded as ancestral to the true cats, for without exception they all display the characteristic and unmistakable features which place them in the sabre-tooth series. The more primitive genera, such as *Dinictis*, possess a dentition which is but slightly modified in the direction of the cats, and cranial foramina resembling those of the early dogs in the presence of an alisphenoid canal, the separa-

tion of the condylar foramen from the foramen lacerum posterius, etc.; the femur has a third trochanter and the humerus an extremely prominent deltoid ridge; the feet are plantigrade and pentadactyl and, like those of many of the viverrines, they are supplied with partially retractile and very incompletely hooded claws. In all probability these structural characters also occurred in the ancestral *Felinæ*, but what distinguishes even the earliest Machairodonts is the elongation and compression of the upper canines, the reduction in size of the inferior ones and the development of bony flanges from the ventral border of the mandible for the protection of the superior tusks. From such beginnings the sabre-tooth series may be traced, with various divagations and side branches, to the Pleistocene *Smilodon*, which in all parts of its structure is extraordinarily like *Felis*, the only important differences consisting in the dentition (which is of similar type) and in the modifications of the skull, which are necessarily correlated with the enormous enlargement of the upper canine tusks.

Seeing, therefore, that the machairodont series is well-nigh complete and that none of its known members is at all likely to prove ancestral to the true cats, there can be little reasonable doubt that the remarkably close resemblance which we observe between *Felis* and *Smilodon* is not directly due to their relationship, but has been independently acquired in the two series and is the outcome of a parallel course of development, continued from the Oligocene to the Pleistocene. If this be true, there can be no *à priori* ground for denying that the same phenomena may have been repeated in the dogs and that Boule's suggestion concerning the derivation of the alopecoids from *Cynodictis* may possibly prove to be correct. In this case, however, the final identity of the two series is even more striking than in the cats and Machairodonts; to verify the suggestion, it will be necessary to recover the missing links of the alopecoid phylogeny and to show that it has followed a course parallel to but independent of that of the thooids.

Another alternative possibility is that the foxes became separated from the principal canine phylum at a comparatively late date, and that, consequently, *Cynodictis* and its allies represent but an abortive side-branch from the main stem. That the separation is of considerable antiquity is shown by the parallel arrangement of the two series to which Huxley has called attention. In both wolves and foxes we find species with microdont and macrodont dentition, with sagittal crests and lyrate sagittal areas, with lobate and non-lobate mandibles. So far, at least, we are almost certainly dealing with independently acquired characters. From the standpoint of present actual knowledge it is more probable that the separation did not take place before the end of the Miocene than that it had already been accomplished in the Eocene, though this conclusion involves the admission that *Cynodictis* had anticipated the foxes in quite a remarkable way. While very far from denying the possibility of such convergence as is implied in Boule's

hypothesis, I think it should not be assumed in a given case except upon the clearest evidence. Whichever of these alternatives be true, it is, in any event, probable that the alopecoids are not of American origin.

Still a third possible solution of the problem concerning the mutual relationships of the wolves and foxes is that *Cynodictis*, or some similar form, is the common ancestor of both lines, and that the supposed early thooids, such as *Daphænus* and *Cynodesmus*, are devoid of permanent phylogenetic significance. This is decidedly the least probable of the three alternatives, for the thooids of the American Oligocene and Miocene seem to form a truly connected series, in which *Cynodictis* has no place. Further, this view involves the assumption that the supposed thooids have independently run a course parallel to that of the true thooids and thus encounters the very difficulty which it was intended to avoid. The conclusion which we reach is, therefore, that the thooids are probably of American origin and that the alopecoids are a branch which the wolf stem gave off after certain of its representatives had established themselves in the Old World.

The thooid genealogy itself is by no means free from difficulties. In a former paper ('94), I suggested that the line begins in *Daphænus* of the White River, and is continued by the John Day *Cynodesmus*, but now that we have learned the remarkable characters of the skeleton, especially of the limbs and feet, of the former genus, this view no longer appears so simple and natural, and its acceptance carries with it some far-reaching and unexpected consequences. In particular, it might be objected to this view that the peculiar differentiation of the feet in *Daphænus* would exclude that form from any place in the direct canine phylum, for it seems *à priori* unlikely that the dogs should first have acquired the power of retracting the claws and should then have subsequently lost it. Indeed, many morphologists are inclined to deny altogether the possibility of this method of evolution. In the present state of knowledge, however, such a denial is at least premature, and there is a considerable body of evidence which goes to show that it does not properly apply in the case of the canine phylum.

In the first place, the John Day genus *Temnocyon*, the osteology of which has been very fully described by Eyermau ('96), appears to be a direct descendant of *Daphnusæ*, with which it agrees in the essentials of structure, though, at the same time, it displays many marked changes and advances. One of the most striking of these changes in the later form is in the great elongation of the limbs and the assumption of a digitigrade gait, both limbs and feet quite closely approximating those of the modern *Canidæ*. Yet even in *Temnocyon* a reminiscence, as it were, of the partially retractile claws of *Daphænus* may be observed in a certain asymmetry of the second phalanges of both manus and pes, which are slightly excavated on the ulnar and fibular sides respectively. While *Daphænus* was a short-limbed, plantigrade or semi-plantigrade form, which, in all

probability, was not cursorial in habits, *Temnocyon*, on the other hand, was undoubtedly cursorial and probably essentially resembled the modern wolves in appearance and habits. In this change to a digitigrade gait and cursorial habit, it seems quite reasonable to suppose that the mode of using the claws should have been changed likewise, the feet being used almost exclusively for purposes of locomotion and the claws losing their importance as weapons and grasping organs. Under these circumstances the power of retraction would become superfluous and tend to disappear, although, as we have seen, *Temnocyon* retains recognizable traces of the structure which permits retraction of the claws. It is true that *Temnocyon* itself is not in the direct line which leads up to the modern *Canidæ*, for the heel of the lower sectorial and the whole of $m \frac{2}{2}$ have become trenchant through the loss of the internal cusps, a curious specialization; but, on the other hand, there is no reason to suppose that it differed in any other important respect from its contemporary *Cynodesmus*, which appears to be a member of the direct phylum.

In the second place, a similar loss of the power of retracting the claws has almost certainly occurred among the *Felidæ*. The hunting leopard or cheetah (*Cynælurus*) has acquired something of the proportions and appearance of the wolves, having very elongate limbs and feet and a running gait which is described as quite different from that of the ordinary cats. Comparing the phalanges of *Cynælurus* with those of *Felis*, some marked differences are at once apparent; in the lateral digits the second phalanx is quite symmetrical and is not excavated on the ulnar (or fibular) side; the excavation is distinctly shown only in the third digit and is much less marked in the fourth. The bony hood of the ungual phalanx is much reduced, leaving more than half the length of the phalanx exposed, and the subungual process is much smaller than in *Felis*. The tarsus, in fact the skeleton of the entire pes, has a canine aspect, and the retractility of the claws is very partial and imperfect. Now, there can be little doubt that *Cynælurus* is not the remnant of a very ancient group, given off from the feline stem at a time when the power of retracting the claws had been but partially attained, but that it was derived from ancestors which differed little from *Felis*. If such a transformation could take place among the cats, there would seem to be no good reason for denying that it might also occur in the dogs.

Unfortunately, the phylogenetic history of the dogs is not made clearer and more intelligible by reason of the new material of *Daphænus*, which has been described in the foregoing pages, and which raises more problems than it solves. I am inclined to believe, however, that *Daphænus* should still be given a place in the canine phylum, for the differentiation of its limbs and feet is hardly of that radical kind which would prevent a subsequent change in the trend of development, and its many resemblances to the early Machairodonts are, at least in part, survivals of primitive conditions, sev-

eral of which, like the shape of the radius, recur in *Cynodictis*. Tending to the same conclusion is the fact that what little is known of the structure of the creodont *Miacis* is of similar composite canine-feline character and it is to that creodont family to which most of the lines of fissipede Carnivora appear to lead back. It may be hoped that the problem will receive its definite solution when we shall have recovered the as yet missing or very imperfectly known dogs from the Uinta, uppermost White River and lowest John Day formations, and are thus enabled to trace the successive changes step by step.

Assuming, then, as probable that *Daphænus* should have a place in the direct canine phylum, the larger question at once arises: What was the relation between the early members of the *Canidæ* and *Felidæ*, and of both of these groups to the other fissipede families? It seems to be a comparatively rare phenomenon among the mammals that parallelism or convergence of development should be manifested in all parts of the structure of two independent lines, though that this may happen is shown by the case of the Machairodonts and felines, to which reference has already been made. Usually, however, parallelism is displayed in a few structures only, such as the dentition, or the feet, or the vertebræ, and the more widely separated any two phyla are at their point of origin, the less likely are they to develop along similar lines. It will be sufficiently clear from the foregoing descriptions that the resemblances between *Daphænus* and the more primitive Machairodonts, such as *Dinictis*, are not only exceedingly close, but that they recur in all parts of the skeleton. The skull, the vertebral column, the limbs and the feet are all so much alike in the two series that, in the absence of teeth, it is often very difficult to decide to which of the two a given specimen should be referred. Such close and general resemblance is *prima facie* evidence of relationship, even though it should have been independently acquired, because parallelism is much more frequent between nearly allied than between distantly related groups. In the present instance, however, there is no reason to infer that the resemblances were separately attained; on the contrary, the evidence now available seems to favor the conclusion that the dogs and cats are derivatives of the same Eocene stock. It cannot be pretended that this conclusion is, as yet, a well-established one, nor can it be so established until we recover the missing links of the canine and feline genealogies. *Daphænus* may eventually prove to be merely an abortive side-branch without phylogenetic significance, though this seems unlikely in view of its relationship to the John Day dogs. On the other hand, when we have learned more of the Uinta dogs, it may appear that all the many resemblances of *Daphænus* to the Machairodonts have been separately attained; but existing evidence does not favor this suggestion either. It seems exceedingly likely that the dogs and cats are more closely related than has hitherto been believed and that they were derived from a common middle or late Eocene progenitor.

On the assumption that the dogs and cats are thus quite closely connected, what can be said concerning the relations of the other fissipede families with these groups and with one another? Of the derivation of the *Procyonidæ* nothing is yet known; the family may be traced back into the Loup Fork without finding essential changes, but beyond that period we lose track of it altogether. The position of the bears and hyænas is reasonably clear, the latter being late derivatives of the viverrines and the former of the dogs, neither family making its appearance until long after the other fissipede groups had become clearly differentiated. The *Viverridæ* have a great many characters in common with both the early dogs and the early Machairodonts; almost all the structural features which are found in both *Daphænus* and *Dinictis* recur also in the viverrines, and the latter again have many points of similarity to *Cynodictis*, as has often been remarked. That the viverrine features of *Cynodictis* are more numerous and apparent than those of *Daphænus* is largely due to the small size of the former, which agrees much better with the stature usual in the recent viverrines. The viverrines thus seem to be derivatives of the same Eocene stock as that which gave rise to both the dogs and the cats, though, perhaps, they are more nearly allied to the latter than to the former, and apparently they have departed less from that primeval fissipede stem than has either of the other families. Aside from the peculiar character of the auditory bulla and the reduced number of the molar teeth, such a genus as *Viverra* would seem to differ but little from the hypothetical Eocene ancestor of all the fissipede families. The *Mustelidæ* represent a quite specialized branch of the fissipedes, but between its earlier and more primitive members and the corresponding representatives of the viverrines are so many structural resemblances that Schlosser does not hesitate to derive them from a common stem. An interesting and significant example of this community of characters among the early representatives of the different fissipede families is given by the *os penis* of *Cynodictis*, which resembles that of the mustelines much more closely than that of the modern dogs. This probably indicates that all of the earlier fissipedes had this bone shaped very much as in the existing mustelines, which have thus retained the primitive form, while in the other families it has become much modified in shape and size. This would explain the apparent anomaly of the very large *os penis* of *Cryptoprocta* which is so different from that of the other viverrines. According to this way of looking at the subject, there was a middle Eocene group of flesh-eaters, perhaps the creodont family *Miacidæ*, which rapidly diverged into four principal branches, the cats, dogs, viverrines and mustelines, all of which families were established in the late Eocene or early Oligocene, and to these should perhaps be added a fifth family, the *Procyonidæ*, though of this we know nothing definite. The Fissipedia are thus probably a monophyletic rather than a polyphyletic group, which was derived from a single creodont family.

It is exceedingly difficult to unravel all this complicated mesh-work of similarities and definitely to distinguish those characters which are due to genetic relationship from those which are merely phenomena of parallelism or convergence. But the important fact remains that in the late Eocene and early Oligocene all of the families of fissipede Carnivora which had then come into existence were very much alike and in all parts of their structure resembled one another much more closely than do their modern representatives. They are obviously converging back to a common term, and the only question is what that common term was and whether we are to look for it in the middle or the lower Eocene. It must be reiterated, however, that natural and probable as this conclusion appears to be, it is only tentative and cannot be demonstrated until the successive phylogenetic stages of each family are much better known than they are at present.

SUMMARY.

1. *Daphænus*, so named in 1853 by Leidy and afterwards referred to *Amphicyon*, is very different from the latter and an entirely distinct genus.
2. The dental formula is: $I \frac{3}{3}$, $C \frac{1}{1}$, $P \frac{4}{4}$, $M \frac{3}{3}$; the premolars are small and simple and are set well apart in the jaws; the sectorials are small and primitive, especially in? *D. Dodgei*, and the molars relatively large, most so in *D. vetus*. The dentition is more like that of the creodont family *Miacidæ* than of the typical modern dogs.
3. The skull is of a very primitive character, with short face, very elongate cranium and high sagittal crest; the cranial cavity is of small capacity and the postorbital constriction is placed far back of the eyes. Large frontal sinuses are present.
4. The occiput is low and broad, with very prominent crest; the paroccipital processes are short and blunt and are widely separated from the tympanic bullæ.
5. The auditory bulla is minute and does not fill up the fossa, exposing the periotic; it probably represents only the anterior chamber, the posterior chamber was either not ossified or was very loosely attached, so that it is lost in all the known specimens.
6. The cranial foramina differ very little from those of *Canis*.
7. The mandible has a short horizontal ramus, varying in its proportions in the different species; the ascending ramus is low and very broad.
8. The brain is remarkable for the small size and simple convolutions of the cerebral hemispheres and the large size of the cerebellum and olfactory lobes.
9. The foramina of the atlas differ from those of the recent dogs and resemble those of the cats.
10. The axis is also of feline character, especially in the shape of the neural spine.
11. The other cervical vertebræ have more prominent zygapophyses, narrower neural arches and higher neural spines than in *Canis*.

12. The thoracic vertebræ probably numbered thirteen ; they resemble those of the modern dogs, except for their longer neural spines, and for the much more prominent anapophyses on the last three vertebræ.

13. The lumbar, probably seven in number, are remarkably large and massive and all their processes are very long ; the appearance of these vertebræ is feline rather than canine.

14. The sacrum is composed of three vertebræ and resembles that of the larger cats in its size and weight.

15. The tail is very long and stout, resembling in its proportions and in the development of the individual vertebræ that of the leopard.

16. The humerus is in most respects like that of the Machairodonts, *Dinictis* and *Hoplophoneus*, having very prominent deltoid and supinator ridges, very low trochlea, large epicondyles and an entepicondylar foramen.

17. The radius is very feline in character, as is seen in the discoidal head, the slender curved shaft and expanded distal end.

18. The ulna is much less reduced than in the modern dogs, and its shape, especially that of the distal end, is much more feline than canine.

19. The only carpal element preserved is the scapho-lunar which is very like that of the Machairodont *Hoplophoneus*.

20. There are five metacarpals which are not at all like those of modern dogs, the pollex being far longer and all of the metacarpals having short, slender, rounded shafts, spheroidal distal trochleæ, and a divergent instead of a parallel arrangement. The contact of mc. ii with the magnum and of mc. iv with the unciform is much less than in the true felines and about as in the Machairodonts.

21. The pelvis is machairodont rather than canine, the ilium being relatively short and narrow, the ischium long, with inconspicuous tuberosity, and the obturator foramen large ; the pubic symphysis is elongate.

22. The femur is not very long in proportion to the size of the animal ; its trochlea is very low and shallow ; a third trochanter appears to have been present.

23. The patella is like that of *Dinictis*, being broad, thin and almond-shaped.

24. The tibia is short and slender and bears considerable resemblance to that of *Dinictis* ; its distal end bears a very large internal malleolus and feebly grooved astragalar trochlea.

25. The fibula is much stouter than in *Canis* and has more thickened ends.

26. The tarsus is, on the whole, of machairodont or viverrine character, but with not a few canine features.

27. The metatarsus has five members, a well-developed hallux being present ; the

character of these is intermediate between those of the dogs and those of the Machairodonts.

28. The phalanges are long and depressed; the second one is excavated on the fibular side, showing that *the claws were partially retractile*, though much less completely so than in the cats; the unguals are straight, compressed and bluntly pointed, and with bony hoods much as in *Canis*.

29. The known species of *Daphænus* are: *D. vetus* Leidy, *D. hartshornianus* Cope, *D. felinus*, sp. nov., ? *D. Dodgei* sp. nov., all from the White River beds, and *D. cuspi-gerus* Cope, from the John Day.

30. The cynoid from the Uinta beds, *Miacis uintensis*, is regarded as the forerunner of *Daphænus*.

31. The small American cynoids of the White River and John Day, and, perhaps, of the Uinta, should be referred to the European genus, *Cynodictis*.

32. The dental formula of *Cynodictis* is: I $\frac{3}{8}$, C $\frac{1}{1}$, P $\frac{4}{4}$, M $\frac{2}{3}$; the premolars are small, the sectorials microdont and quite viverrine in appearance, but more trenchant than those of *Daphænus*, and the tubercular molars are small.

33. The skull has a very viverrine look; the face is short, the cranium long, though shorter and fuller than in *Daphænus*, and the postorbital constriction is near the orbit; the sagittal crest is low and weak, and in the small *C. lemur* is replaced by a lyrate area.

34. There are no frontal sinuses.

35. The occiput is low and broad, the crest inconspicuous and the paroccipital processes are small and not in contact with the bullæ.

36. The auditory bulla is very large and the posterior chamber fully ossified.

37. The cranial foramina are like those of *Canis*, save for the visible carotid canal.

38. The mandible has a short, slender horizontal ramus and the ascending ramus is much narrower than in *Daphænus*.

39. While the cerebral hemispheres are larger and better convoluted than those of *Daphænus*, they are smaller and have fewer, straighter sulci than in the modern *Canidæ*; the olfactory lobes are large and the cerebellum complex.

40. The atlas has short transverse processes and its foramina are feline in character.

41. The axis is much like that of *Viverra*.

42. The other cervicals are of canine type.

43. The thoracic vertebræ are small and have high, slender spines; on the last two are prominent anapophyses.

44. The lumbar region is long, heavy and arched upward; it is composed of seven vertebræ, which have very long transverse processes and low, slender spines. Anapophyses are large anteriorly, but disappear on the sixth.

45. The tail was very much as in such viverrines as *Herpestes*.

46. The sternum is of a generalized fissipede character, without special resemblance to either dogs or viverrines.

47. The scapula has little resemblance to that of *Canis*, being low and broad, with spine placed nearly in the middle of the blade; the metacromion is very large and the acromion exceedingly long and prominent, from which it may be inferred that the clavicles were less reduced than in the modern dogs; the coracoid is very large.

48. The humerus is much more viverrine than canine in appearance, having, like *Daphænus*, very prominent deltoid and supinator ridges, a low trochlea and entepicondylar foramen, but no supratrochlear perforation.

49. The radius is like that of *Daphænus*, except for the immense styloid process.

50. The ulna is much stouter than in the recent dogs and differs from that of *Daphænus* in having the distal radial facet sessile.

51. The carpus contains a scapho-lunar which is quite like that of *Canis*; the pyramidal is viverrine and the pisiform quite peculiar in shape; a radial sesamoid appears to have been present; the trapezoid and magnum are canine, while the unciform is viverrine.

52. The metacarpus has five elements, which are very short and slender like those of the civets.

53. The pelvis is, in general, canine, but primitive in the elongation of the post-acetabular portion.

54. The os penis is very large and shaped like that of *Cryptoprocta* and the mustelins.

55. The femur is elongate and differs little from that of the recent dogs, except in the presence of a small third trochanter and in the narrow, shallow rotular trochlea.

56. The patella is wide, thin and scale-like, herpestine in shape.

57. The tibia is of nearly the same length as the femur, and its distal end is like that of *Daphænus* and *Dinictis*, but more deeply grooved.

58. The fibula is relatively stout.

59. The general appearance of the pes is viverrine and has many resemblances to that of *Daphænus* and some to that of *Canis*.

60. A well-developed hallux is present and the metatarsals exceed the metacarpals in length much more than they do in *Canis*.

61. The phalanges differ materially from those of *Daphænus* in that the claws are little or not at all retractile; the unguals have but rudimentary hoods.

62. The skeleton of *C. geismarianus* was very herpestine in proportions, while that of *C. gregarius* was more like that of a very small fox in which the hind leg much exceeded the fore leg in length.

63. The known American species of the genus are: *C. gregarius* Cope and *C. lippincottianus* Cope (the latter doubtful) from the White River, and *C. gregarius* Cope, *C. geismarianus* Cope, *C. latidens* Cope and *C. lemur* Cope, from the John Day.

64. The dogs are represented in the Uinta by two lines, ? *Cynodictis* and *Miacis*, the former continued through the White River and John Day and the latter apparently passing into *Daphænus* of the White River, and through this into *Temnocyon*, *Hypotemnodon*, *Cynodesmus* and *Enhydrocyon* of the John Day, *Oligobunis* of this formation being probably an immigrant from the Old World.

65. M. Boule's hypothesis that the alopecoids are derived from *Cynodictis* and the thooids from *Amphicyon* implies an improbable degree of convergent development, but it is not to be rejected as impossible. According to present evidence the alopecoids arose relatively late from the thooid stem.

66. The thooid line appears to be *Miacis*—*Daphænus*—*Cynodesmus*—*Canis*, the retractile claws of *Daphænus* having been changed when the digitigrade gait and cursorial habit were assumed.

67. The very many resemblances between *Daphænus*, *Cynodictis* and *Diictis* were probably not independently acquired, but point to a common Eocene ancestor.

68. The early members of the canines, felines, mustelines and viverrines all have a great many more structural features in common than do their existing representatives and would seem to converge to a single Eocene type, which may prove to be the creodont family *Miacidæ*. The hyænas and bears belong to a later cycle of development and were derived, the former from the viverrines and the latter from the dogs.

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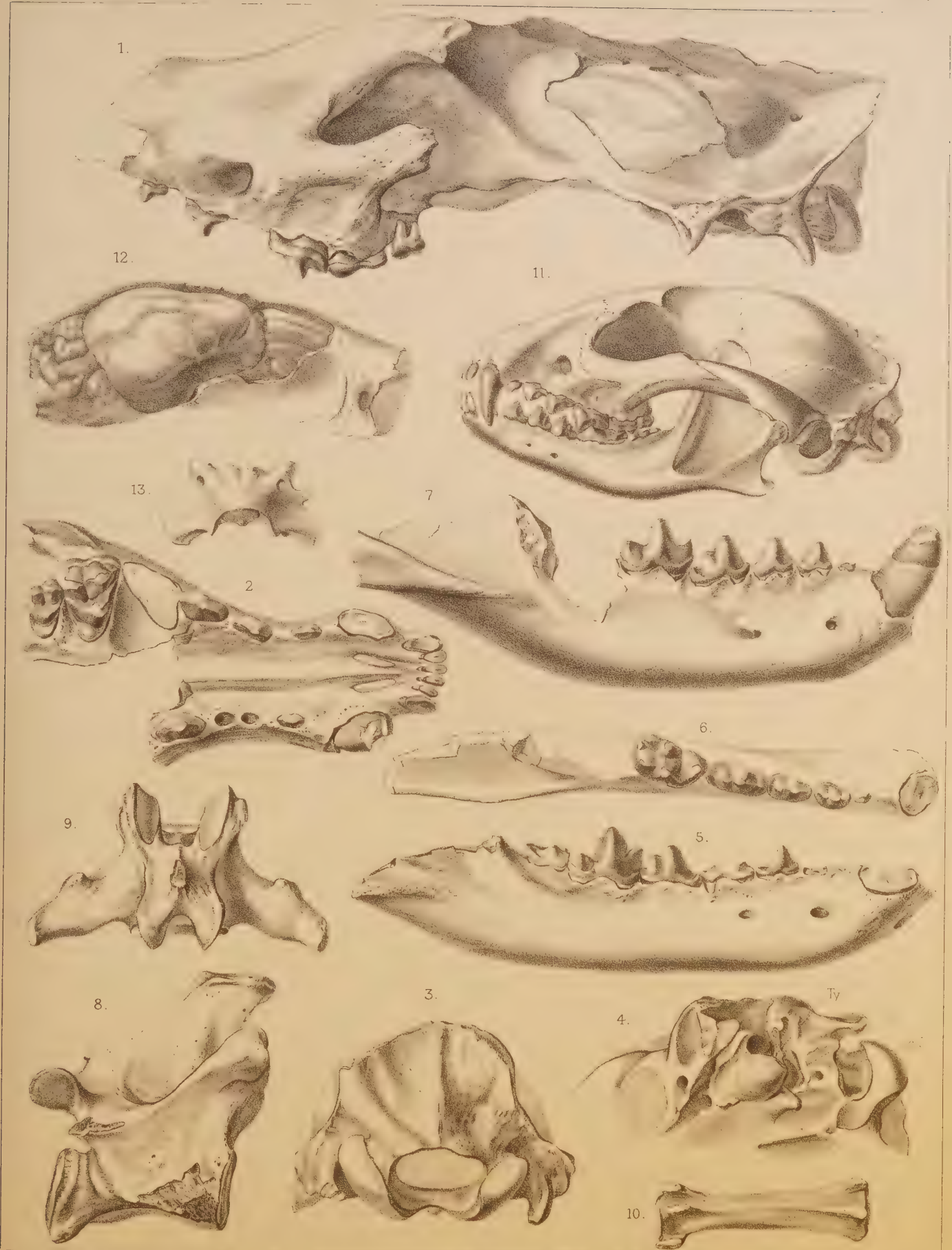
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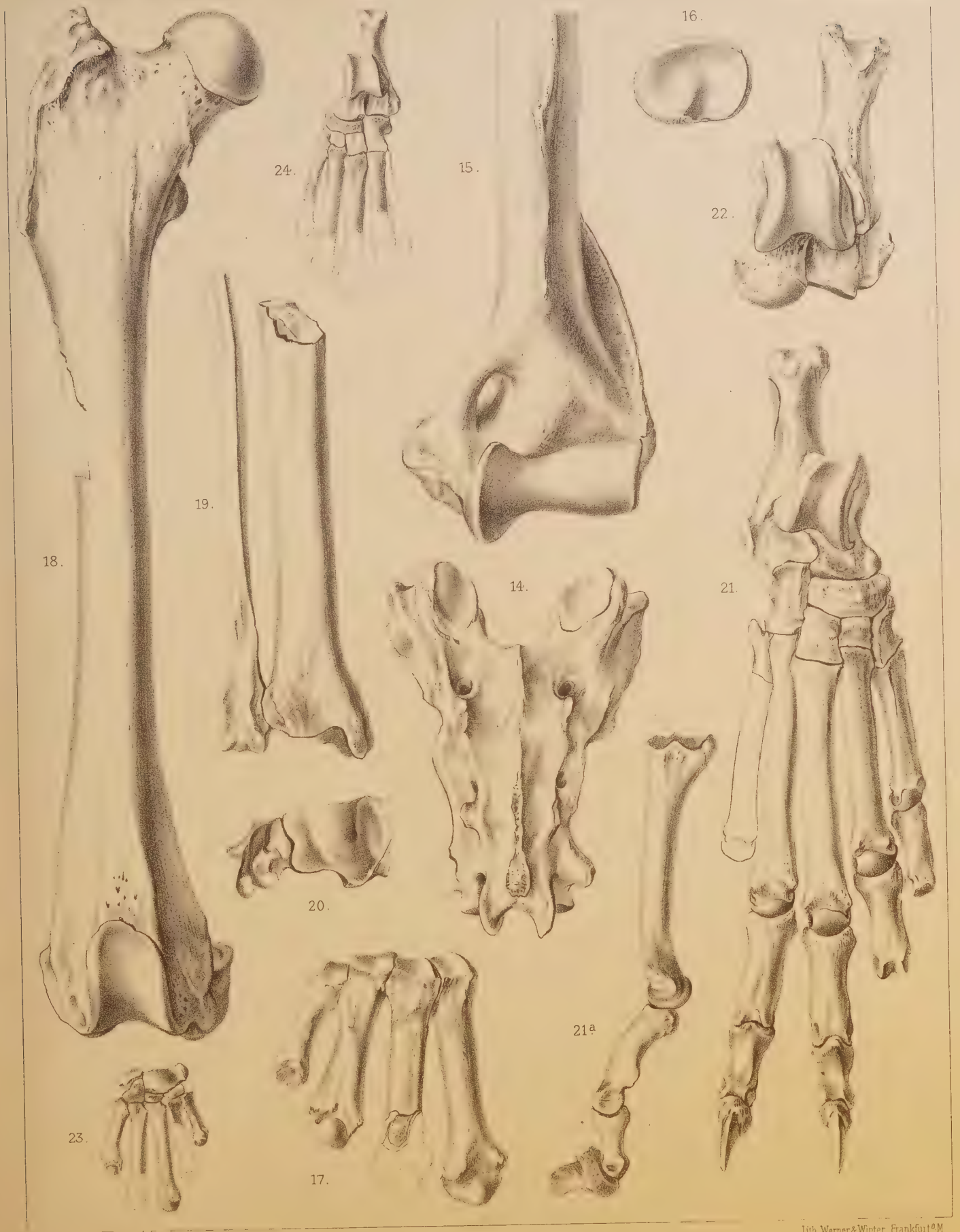
Plate XIX.

- Fig. 1. *Daphænus hartshornianus* Cope. Side view of skull.
 Fig. 2. " " " Palate and teeth of a second specimen.
 Fig. 3. " " " Occiput ; same specimen as Fig. 1.
 Fig. 4. " " " Basis cranii of same individual : *ty.*, tympanic ; *f.*, fossa behind bulla ; *c. f.*, condylar foramen.
 Fig. 5. *Daphænus hartshornianus* Cope. Right lower jaw.
 Fig. 6. *Daphænus Dodgei*, sp. nov. Lower teeth, crown view.
 Fig. 7. " " " " Side view of right lower jaw.
 Fig. 8. *Daphænus vetus* Leidy. Lumbar vertebra, from the side.
 Fig. 9. " " " Anterior caudal vertebra from above ; same individual.
 Fig. 10. " " " Posterior caudal vertebra from the side ; same individual.
 Fig. 11. *Cynodictis gregarius* Cope. Side view of skull (lower canine broken away).
 Fig. 12. " " " Brain cast from the right side : *olf.*, olfactory lobe ; *rh.*, rhinal sulcus ; *f.*, frontal bone, showing the absence of sinus.
 Fig. 13. *Cynodictis gregarius* Cope. Atlas from above.
 (*All figures natural size.*)

Plate XX.

- Fig. 14. *Daphænus vetus* Leidy. Sacrum from above ; same specimen as Figs. 8, 9, 10.
 Fig. 15. *Daphænus felinus*, sp. nov. Lower end of humerus, front view.
 Fig. 16. " " " " Proximal end of radius ; same individual.
 Fig. 17. " " " " Metacarpals i-iv of left manus ; same specimen.
 Fig. 18. *Daphænus vetus* Leidy. Right femur, front view ; same specimen as Fig. 14.
 Fig. 19. *Daphænus hartshornianus* Cope. Lower half of right tibia and fibula.
 Fig. 20. " " " Distal ends of same.
 Fig. 21. " " " Right pes ; same individual.
 Fig. 21a. " " " iii digit, from tibial side ; same individual.
 Fig. 22. *Daphænus vetus* Leidy. Left calcaneum and astragalus ; same specimen as Fig. 14.
 Fig. 23. *Cynodictis gregarius* Cope. Left manus, front view.
 Fig. 24. " " " Left pes, front view. (Specimens seen since this plate was drawn show that the metatarsals should have been made considerably longer.)
 (*All figures natural size.*)





ARTICLE IX.

CONTRIBUTIONS TO A REVISION OF THE NORTH AMERICAN BEAVERS, OTTERS AND FISHERS.

(Plates XXI-XXV.)

BY SAMUEL N. RHOADS.

Read before the American Philosophical Society, May 6, 1898.

An unusually fine series of the skins and skulls, with reliable data and measurements, of the beavers, otters and fishers of the United States and Canada having lately come into the custody of the writer, it is thought advisable to publish the results of a study of the various nominal forms of these mammals and briefly discuss the nomenclature involved. Owing to a lack of specimens from some regions whose faunal conditions are known to produce in many other mammals well-recognized geographic variations, this paper must be considered rather as a contribution to the subject, and in no sense a complete synopsis. The area covered by this study comprises solely that part of North America north of Mexico, no attempt being made to discuss the relationships of the tropical species.

To Mr. Outram Bangs the author acknowledges his gratitude for a most valuable loan of skins and skulls of nearly every species and race recorded in these pages. To the kindness of Mr. F. W. True, of the National Museum, is due the loan of a series of skulls of the Alaskan otter.

The North Carolina Department of Agriculture has courteously loaned two skins and four skulls of beavers recently killed in Stokes county of that State through the kind offices of Mr. H. H. Brimley, the Curator of the State Museum.

Aid has likewise been generously given by Dr. J. A. Allen, Dr. C. Hart Merriam, Dr. T. S. Palmer, Mr. Gerrit S. Miller, Jr., Dr. M. W. Raub and Mr. C. S. Brimley.

THE BEAVERS OF NORTH AMERICA.

Contrary to evidence which must eventually be accepted by all zoölogists, the American beaver, *Castor canadensis* Kuhl, is still considered by many eminent authorities as

specifically the same as the *Castor fiber* Linnæus of Europe. In 1897, Dr. E. A. Mearns described* a subspecies of the typical Canadian animal, naming it *Castor canadensis frondator* and assigning its habitat to the "southern interior area of North America, ranging north from Mexico to Wyoming and Montana." This appears to be the first attempt in literature to formally subdivide the American beaver, a species whose constancy of characters over the vast and varied habitat which it frequents had hitherto been unquestioned. There can be no doubt as to the tenability of Dr. Mearns' "Broad-tailed Beaver" as distinguished from the Hudson bay animal, whose habitat Kuhl designated as "*ad fretum Hudsoni*" in his original description of *canadensis*.

It is probable that the beavers inhabiting the Carolinas, Georgia, Alabama, Mississippi and Tennessee are equally entitled to subspecific rank. So rare has the beaver become in these States, however, it would probably be impossible to verify such a prediction with specimens now in our museums.†

From what we know of the relationships of the representatives of our eastern species inhabiting the Pacific slope, we are led to expect that the beaver of that region would also prove separable from *canadensis*. A very complete series of skulls, with three adult and three young skins from the Cascades of Washington and Oregon, shows this to be the case.

Fortunately the synonymy of the American beaver is not involved and requires no elucidation in this connection, as is shown by reference to Dr. J. A. Allen's *Monograph of the North American Rodentia*. A synopsis of the American forms is herewith presented.

CANADIAN BEAVER. *Castor canadensis* Kuhl.

Plate XXI; Fig. 3. Plate XXII; Fig. 3.

Castor canadensis Kuhl, *Beitr. Zool.*, 1820, p. 64.

? "*Castor americanus* F. Cuvier, *Hist. des Mam. du Mus.*, 1825" (*fide* Brandt in *Kennt. Säugt. Russl.*, 1855, p. 64).

Castor fiber americanus Richardson, *Faun. Bor. Amer.*, I, 1829, p. 105.

Castor fiber var. *canadensis* J. A. Allen, *Monog. N. Amer. Rod.*, 1877, p. 444.

Type Locality.—Hudson bay ("*ad fretum Hudsoni*" Kuhl).

Geographic Distribution.—Northeastern North America, from the northern limit of trees south to the United States and west to the Cascade mountains; intergrading east of the Mississippi river into subspecies *carolinensis*, south-centrally into subspecies *frondator* and westwardly into subspecies *pacificus*.

* *Proc. Nat. Mus.*, Vol. XX (adv. sheet, March 5, 1897).

† As will be seen later, such specimens have since come to hand and are described as *Castor canadensis carolinensis*.

*Color.**—Winter pelage, above, including sides, dark bay or blackish brown, tipped with chestnut or russet, becoming pure chestnut on top and sides of head and on chin, jaws and sides of neck. Rump and thighs purer chestnut. Ears black. Hair of feet, legs and under parts seal brown.

Anatomical Characters.—Size, smallest of the American forms. Scaly portion of tail more than twice as long as wide; hind foot with claw about 175 mm. Skull wide for its length; maximum size of skull 136 by 99 mm. in a New Brunswick example, No. 31, collection of E. A. and O. Bangs. Rostrum and nasals relatively short and wide, the nasal bones averaging more than half as wide as long and extending but little behind the premaxillaries. Upper molar dentition wide and heavy, the crowns oblique, triangular and very wide anteriorly.

Measurements.—Of a large, typical, adult male specimen from Quebec, No. 3825, collection of E. A. and O. Bangs (measurements made by collector from newly killed specimen). Total length, 1130 mm.; tail vertebræ, 410 mm.; scaly portion of tail (dry meas. from skin), 263 by 122 mm.; hind foot, 176 mm.; length of skull, 132 mm.; breadth of skull, 93 mm.; length of nasal bones, 46 mm.; breadth of nasals, 21.4 mm.†

Remarks.—The above diagnosis is taken mainly from the Quebec specimen, because of the authentic measurements and superior condition of the skin and pelt. The average beaver from the Hudson bay regions, however, is somewhat lighter colored than this specimen, which, in its darkness and richness of shade, rivals the best examples of *pacificus*. In size, and ratio of length to width, the skull of the Quebec specimen is typical, but the nasals are too narrow to serve as a standard for *canadensis*, whose nasals average wider than *pacificus* and narrower than *frondator*. In general terms, *canadensis* differs from *frondator* in smaller size, narrower tail, much darker coloration and narrower nasals. It differs from *carolinensis* in smaller size, narrower, longer nasals and somewhat darker coloration. From *pacificus* it differs in smaller size, lighter coloration, wider nasals and broader skull. Subspecies *pacificus* differs from *frondator* in larger size, greatly narrowed and lengthened tail-paddle, rostrum and nasals, and in its dark coloration. In color *frondator* is decisively and uniformly lighter than eastern *canadensis* and *carolinensis* and western *pacificus*, but darkened *canadensis* (not melanistic) are nearly as dark as *pacificus*. In size, *pacificus* is much the longest of the three, with very long hind foot and tail. Its skeleton is slenderer and weaker in every part as compared with the massive frame of *canadensis* and *frondator* of same age. *Carolinensis* is nearly of the color of

* Ridgway's *Nomenclature of Colors* is the standard used throughout this paper.

† The narrow nasals of this specimen are an exception, the average of several east Canadian specimens showing the ratio of length to breadth as less than two to one.

lighter hued *canadensis*, but agrees with all the other characters of *frondator*, to which it seems most nearly allied in cranial and caudal characters.

Specimens Examined.—New Brunswick, 1 skull; Quebec, 1 skin with skull; Canada (?), 3 skulls, 1 skeleton, 2 mounted skins; Ft. Simpson, N. W. T., 1 mounted skin; Idaho, 1 skin with skull.

CAROLINIAN BEAVER. *Castor canadensis carolinensis*, subsp. nov.

Plate XXIII; Figs. 1 and 2.

Type Locality.—Dan river, near Danbury, Stokes county, North Carolina. Type No. z.607, old ad. ♂, in the collection of the North Carolina State Museum, Raleigh, N.C. Collected by a trapper in flesh for the Museum, April, 1897.

Geographic Distribution.—Carolinian fauna, south into the Austroriparian.

Color.—Of type and topotype: Overhair of upper head, neck, back and sides, bright hazel. Underfur of same parts, seal brown. Hinder back and rump lightening from hazel to cinnamon rufous and then to tawny olive near base of tail. Vent and under base of tail, dark, rich burnt umber. Ears pale blackish. Sides of head below eyes light hair brown, shaded with pale cinnamon rufous. Feet bistre. Below, from throat to vent, dark broccoli brown with wood-brown tips to overhair.

Anatomical Characters.—Size large, larger than *canadensis*, with relatively much broader tail, as in *frondator*.

Skull large and broad, with very short, broad nasals. In the type the base of nasals does not reach back to the line connecting the anterior walls of the orbits. Rostrum very short and broad. Audital bullæ remarkably contracted laterally, with a strongly developed osseous column on the outer wall and the transverse diameter less than the longitudinal. Incisors weak, narrowed; molars large, with triangular crowns. Pelage short and harsh as compared with *canadensis*.

Measurements.—Of the type, from carcass: Total length, 1130 mm.; scaly portion of tail, 279 by 158 mm.; hind foot, 184 mm.; ear, from crown, 21 mm.; length of skull, 148 mm.; breadth of skull, 107 mm.; length of nasals, 43.5 mm.; breadth of nasals, 29 mm. Of the topotype (ad. ♂): Total length, 1080 mm.; scaly portion of tail, 260 by 146 mm.; hind foot, 174 mm.; ear from crown, 23 mm.

Remarks.—The two skins and four skulls upon which the above diagnosis of *carolinensis* is based were secured, just before the completion of this paper, from the authorities of the State Museum of North Carolina. They are intended to form a group exhibit in the State Museum, and have been carefully measured by the curator, Mr. H. H. Brimley, while yet in the flesh. The old male which forms the type had lost one of its fore feet,

apparently in a trap, some years previous to its final capture, but its evident health and great size show that it had suffered little inconvenience from the loss of the member.

The strong cranial and caudal affinities which this beaver shows to *frondator* as distinguished from *canadensis* indicate that it is more closely related to the western form. In color, however, it shows a nearer approach to *canadensis*, as, in fact, do many other animals of similar distribution and racial differences. The Mississippi and Louisiana beavers are undoubtedly, from what I can hear from the furriers, the darkest and thinnest pelted of our American beavers, but their separability from what I have named *carolinensis* is not probable. They may be considered as belonging to *carolinensis* rather than to *frondator*.

Specimens Examined.—Stokes county, North Carolina, 4.

SONORAN BEAVER. *Castor canadensis frondator* Mearns.

Plate XXI; Fig. 2. Plate XXII; Fig. 2.

Castor canadensis frondator Mearns, *Proc. U. S. Nat. Mus.*, XX, adv. sheet, Mar. 5, 1897.

Type Locality.—San Pedro river, Sonora, Mexico, near monument No. 98, of the Mexican boundary line.

Geographic Distribution.—Southern interior of North America from Mexico to Wyoming and Montana, intergrading northwardly into *canadensis*, southeastwardly into the trans-Mississippian *carolinensis* and westwardly into *pacificus*.

Color.—Much paler than *canadensis* or *carolinensis*. "Above russet, changing to chocolate on the caudal peduncle above and to burnt sienna on the feet; toes reddish chocolate. Below grayish cinnamon, brightening to ferruginous on the under side of caudal peduncle. Sides wood brown enlivened by the tawny-olive color of the overhair."* A specimen from Red Lodge, Montana (No. 32, collection of E. A. and O. Bangs), taken in November, is wood brown above and below, the longer overhair of upper pelage washed with pale rusty.

Anatomical Characters.—Size large, exceeding average of Hudson bay beaver, with a longer foot and broad tail. Scaly portion of tail less than twice as long as wide, hind foot with claw about 185 mm. Skull massive, large, with short rostrum and very wide, short, tumid nasal bones, the average skull probably exceeding *canadensis* in size, certainly exceeding it in relative width to length and in the relative breadth of the nasals. Upper molar dentition as in *canadensis*.

Measurements.—Of the type: Total length, 1070 mm.; tail vertebræ from anus, 360 mm.; scaly portion of tail, 290 by 125 mm.; hind foot, 185 mm.; length of skull, 133

* Quoted from Dr. Mearns' original description (*l. c.*) of type.

mm.; breadth of skull, 99 mm. Maximum length of old males, measured by Dr. Mearns, 1130 mm.; of the tail paddle, 285 by 155 mm.

Remarks.—Dr. Mearns' comparisons of *frondator* with *canadensis* were evidently not made with the largest specimens of the latter, as I have examined some whose cranial and body measurements are about equal to the maximum recorded by him for *frondator*. Nevertheless, there is little doubt that the larger size of average *frondator* is well established. Its long hind foot, broad tail and light coloration distinguish it immediately from *canadensis*. Its approach to *pacificus* is solely along the line of great size as indicated by the length of body and hind foot, but in cranial characters, as also in color, it is farthest removed from that race. The close anatomical relation of *frondator* to *carolinensis* has been mentioned.

Specimens Examined.—Montana, 1 skin with skull; Wyoming, 1 skull.

PACIFIC BEAVER. *Castor canadensis pacificus*, subsp. nov.

Plate XXI; Fig. 1. Plate XXII; Fig. 1.

Type Locality.—Lake Kichelos, Kittitass county, Washington; altitude about 8000 feet. Type, No. 1077, ad. ♀, in the collection of S. N. Rhoads; collected in April, 1893, by Allan Rupert.

Geographic Distribution.—Pacific slope, of America, from Alaska to California.

Color.—Above with very uniform, dark and glossy reddish chestnut overhair, almost concealing along dorsum the seal-brown underfur. Top of head like back; sides of head, throat, rump, thighs and vent not decidedly lighter than back and belly as in the other forms, these parts paling to walnut brown. Overhair of sides and under parts, between seal brown and broccoli brown; under fur of belly drab gray at the roots; hind feet dark seal brown; fore feet and limbs, dark wood brown. Ears black.

Anatomical Characters.—Size, largest of the *canadensis* group, but of more slender build, the skeleton throughout being of much greater longitudinal and lesser lateral dimensions than in the other forms. Tail and hind foot relatively long. Skull large, relatively narrow, with long, narrow rostrum and nasals, the latter with outer margins nearly parallel and reaching basally decidedly beyond the premaxillaries. Upper molar dentition weak, the crowns of molar teeth rectangular.

Measurements.—Of the type from carcass: Total length, 1143 mm.; tail vertebræ, 330 mm.; (from relaxed skin) scaly portion of tail, 295 mm. by 122 mm.; hind foot, 185 mm.; length of skull, 142 mm.; breadth of skull, 101 mm.; length of nasals, 53.6 mm.; breadth of nasals, 24 mm.; average length and breadth of five skulls from Tacoma and Lake Kichelos, Washington, 144 mm. by 99 mm.; average nasal length and breadth of same, 54 mm. by 23 mm.

Remarks.—Reliable measurements of only one adult skin specimen (the type) of *pacificus* were accessible. An adult mounted specimen from Josephine county, Oregon, in the Wagner Institute, Philadelphia, confirms the color and measurements of the type so far as the latter can be ascertained from the stuffed animal.

Pacificus, like its associates, *Mustela americana caurina* and *M. canadensis pacifica* of the Pacific slope regions, is distinguishable by its rich and deep coloration from its darkest trans-Cascadian representatives. No specimens have come to hand from Alaska, but undoubtedly, from what we know of other species found there as well as from the accounts of trappers and furriers, the Alaskan coast beaver represents the maximum of size* and the greatest richness and depth of fur coloration seen in American beavers.

Specimens Examined.—Washington, Tacoma, 1 skeleton, 1 skull; Lake Kichelos, 1 adult skin with skull, 3 young skins with skulls, 1 skeleton, 12 separate skulls; Oregon, Josephine county, 2 mounted specimens; British Columbia, (?) Sumas, 1 skull; † Victoria, 1 skull.

THE OTTERS OF NORTH AMERICA.

As Mr. Oldfield Thomas has shown in his "Preliminary Notes on the Species of Otter," published in 1889 in the *Proceedings of the London Zoölogical Society*, the characters and nomenclature of the North American species are in great need of study. Dr. Elliot Coues has elucidated with sufficient clearness, in his *Monograph of the Mustelida*, the habits and characters, and, to some extent, the synonymy of the typical Canadian otter, *Lutra hudsonica* Lacépède. Its relations, however, to other nominal species, especially to the otters of the Pacific slope of America from California northward, demand investigation.

As in the case of the American beaver, just treated, this paper has to do solely with one central Canadian type and its subspecies found in America north of Mexican territory.

Avoiding a general preliminary discussion of the rather perplexing questions of nomenclature and geographic variations and distribution, I will present these in order in the more formal and detailed synopses which follow.

* Dr. Allen's measurements of Alaskan skulls, page 447 of the *Monograph of N. A. Rodentia*, do not indicate unusual size, but as we have no precise locality given they may not have come from the coast region, and, therefore, do not represent *pacificus*.

† This skull (No. 5545, ♂, coll. of E. A. and O. Bangs) is the largest of which I find any record, measuring 154 by 108 mm. The next in size is No. 2146, U. S. Nat. Mus., from Nebraska, recorded by Baird. Its size was 147 by 105.5 mm. Unlike all my *pacificus* specimens, No. 5545 has very wide convex nasals.

HUDSONIAN OTTER. *Lutra hudsonica* ("Lacépède," Desmarest).

Plate XXIV; Figs. 1 and 2.

Mustela lutra Linn., *canadensis* Schreber, *Säuget.*, III, Pl. CXXVI, B. (dated 1778 on title-page, but, according to Sherborn, the text of Vol. III was published in 1777 and this plate in 1776).

Mustela (lutra) canadensis Kerr', *Linn. An. Kingd.*, I, 1792, p. 173 (see Thomas, *Proc. Zool. Soc. Lond.*, 1889, p. 197, and Allen, *Bull. Amer. Mus. N. Hist.*, VII, 1895, p. 188).

"*Mustela hudsonica* Lacép.[ède]," Desmarest, *Nouv. Dict. d'Hist. Nat.*, XIII, 1803, p. 384; (*Nouv. Ed.*) 1817, p. 219.

Lutra canadensis J. Sabine, *App. Frankl. Jour.*, 1823, p. 653, and of nearly all subsequent authors (not *L. canadensis* F. Cuvier, *Dict. Sci. Nat.*, 1823, p. 242; see O. Thomas, *l. c.*, p. 197).

Lutra hudsonica F. Cuvier, *Suppl. Buff.*, I, 1831, p. 194; Merriam, *N. Amer. Fauna*, No. 5, 1891, p. 82.

Lataxina mollis Gray, *List Mamm. Brit. Mus.*, 1843, p. 70.

Lutra destructor Barnston, *Canad. Nat. and Geolog.*, VIII, 1863, p. 147, Figs. 1 to 6.

Type Locality.—"Ou la trouve au Canada sur les bords de la mer."

Geographic Distribution.—Northern North America from the Arctic ocean southward into the United States and from the Atlantic ocean to the Cascade mountains; intergrading southeastwardly into subspecies *lataxina* F. Cuvier and *vaga* Bangs, southcentrally into subspecies *sorone* Rhoads, and westwardly into subspecies *pacifica* Rhoads.*

Color (taken from two specimens in the Bangs collection, No. 5638, yg. ad. ♂, Annapolis, Nova Scotia, November 23, 1896, and No. 4190, ad. ♀, Upton, Me., October 25, 1895).—Above, dark seal brown from nose to tip of tail, darkest posteriorly, below from breast to tail between broccoli and vandyke brown in the Nova Scotia specimen and between seal and vandyke brown in the Maine specimen. Head and neck below a line running from nose to lower base of ear and base of foreleg light Isabella color anteriorly darkening on lower neck to wood brown in the Nova Scotia animal. In the Maine specimen the neck is Prout's brown. Feet, legs and tail corresponding to darker shades of upper and lower body. A summer specimen from New Brunswick is dark, vandyke brown, but little paler below than on back, and darker than winter specimens of *lataxina* from Maryland.

* The otters of Louisiana and Mississippi are stated by furriers to be very dark and light-pelted, resembling South Florida and Gulf-coast skins. No specimens having been examined, they are referred to *vaga*.

*Anatomical Characters.**—Size, medium (exceeded by *vaga*, *sonora* and *pacifica*). Tail relatively short. Inferior webs of feet and interspace between posterior and anterior callosities of manus, densely haired. Hind foot with claw about 125 mm. in old adults; but so variable as to have little diagnostic value. Total length rarely exceeding 1100 mm. Skull—size, medium (greatly exceeded by *vaga* and *pacifica*). Teeth large, crowded longitudinally upon each other and obliquely overlapping. Postorbital neck of frontals relatively short and wide, its superior ridge on a plane with nasals and occipital crest. Mastoid width much less than zygomatic width. Postorbital processes short and stout. Audital bullæ large, tumid, rising abruptly from the sides of basioccipital.

Measurements.—See tables.

Remarks.—Variations in the size of adult otters from apparently the same region seem remarkable at first sight, but I find that these are not always to be attributed to sex (for the female otter sometimes reaches near to the average size of the males), but to environment. The otters of the Alleghany mountain streams are uniformly smaller than those of the tide-water creeks and rivers of the Atlantic seaboard. This rule applies from Labrador to Florida and is undoubtedly the result of the relative difficulty of obtaining food and securing shelter from enemies in the two kinds of habitat. On the other hand, this difference lies wholly within the limitations of individual variation and in no sense affects the well-defined cranial and other characters which distinguish the races and species hereafter defined. It has to do solely with size, not with proportions. In a letter from Mr. C. S. Brimley, of Raleigh, North Carolina, the same feature is alluded to where he states: "A trapper of our acquaintance says that otters from the saltmarshes of eastern North Carolina average considerably larger than the otters of the small streams of the central part of the State."

There is rarely to be found a case in mammalian nomenclature more puzzling than that of the first tenable name of the Hudsonian otter. Its synonymy involves that of the mink and the fisher as well as the questions of priority of publication of Erxleben's and Schreber's great works on the Mammalia, and the tenability of plate names. I have consulted Drs. C. H. Merriam and T. S. Palmer at length on these questions and have accepted their ruling as to the first tenable name of the Hudsonian otter being *Lutra hudsonica* Lacépède and that of the northeastern mink to be *Putorius vison* Schreber. In regard to the name of the fisher, however, I prefer to abide by Canon XLIII of the Code of the American Ornithologists' Union, which accepts, under certain conditions, the names of species originally published on plates, which Drs. Merriam and Palmer and Mr. Sherborn do not accept. Returning now to the abstract of synonymy as given above for the Hudsonian otter, the case may be concisely stated thus: *Mustela lutra*

* The diagnostic value of the nose pad has no significance in this study of the relationships of a monotypic group.

canadensis Schreber is a plate name published (*fide* Sherborn) in 1776, and is the earliest applied to this otter. It would stand (A. O. U., Canon XLIII) were it not unquestionably applied and intended by Schreber merely as a geographic name without reference to its specific relations to "*Mustela lutra* Linn." For this reason alone it should be discarded. Furthermore, the name *Mustela canadensis* was used by Schreber on a previous plate in the same volume (Pl. No. 126) in the specific sense for the fisher. This plate was also (*fide* Sherborn) published in 1776, one year before the text, which was published in 1777, and the bound volume of text and plates were dated 1778. In 1777, Erxleben published a description of the fisher and named it *Mustela pennantii*, by which name it has been since designated by authors generally. As this name is antedated by the tenable plate-name *Mustela canadensis* of Schreber by one year, I adopt it as the name of the fisher of Pennant from the northeastern United States. Erxleben published in the same work a description of an animal which he named *Mustela canadensis*, and which Baird and Coues have considered applicable to the mink, and the acceptance of the dates on the title-pages of Schreber's (1778) and Erxleben's (1777) works would give priority to Erxleben's name and displace *Mustela vison* of Schreber. But Sherborn's emendation of these dates makes *M. canadensis* of Erxleben for the mink untenable, it being preoccupied by Schreber's plate-name *M. canadensis* for the fisher, as stated above. Besides this fact, Dr. Merriam considers that Erxleben's description of *M. canadensis* also applies to the fisher and the marten in such a way as to make it untenable for any species.

Returning to the search for a first name for the otter, we find Kerr's name, *M. canadensis* of 1792, to be unavailable because he placed it under the old genus *Mustela*. Next in order appears to be the name *hudsonica*, which is accredited to Lacépède, in an article on the Canadian otter in the first edition of the *Nouvelle Dictionnaire d'Histoire Naturelles*, which is signed "Desm." I have not examined this reference personally, but am indebted to Dr. J. A. Allen for a transcript of these facts from the only known copy of the work in America which appears to be available, belonging to the library of the American Museum of Natural History. In agreement with my previous rendering of manuscript names, and on the supposition that Desmarest was the real author and publisher of this name and description of *hudsonica*, I cite it as *Lutra hudsonica* ("Lacépède," Desmarest). I agree with Dr. Merriam that this name should stand for the otter of eastern Canada. Frederick Cuvier seems to have been the first to place this animal in the genus *Lutra* under the Lacépède-Desmarest name *hudsonica* in 1831.

The *Lataxina mollis* of Gray and the *Lutra destructor* of Barnston are no doubt synonyms of *hudsonica*.

Specimens Examined.—Labrador, Okak, 1 skull; Grand river, 1 skull; New

Brunswick, Restigouche river, 1 skin; Nova Scotia, Annapolis, 1 skin with skull; Maine, Upton, 1 skin with skull; Bucksport, 1 skull; Massachusetts, Kingston, 1 skin with skull; Westford, 1 skull; Canton, 1 skull; Missouri, 1 skull; British Columbia, Vernon, 1 skull; Alaska, Tanana river, 1 skull.

CAROLINIAN OTTER. *Lutra hudsonica lataxina* (F. Cuvier).

Plate XXIV; Fig. 4.

Lutra lataxina F. Cuvier, *Dict. des Sci. Nat.*, 1823, p. 242.

Type Locality.—South Carolina.

Geographic Distribution.—Carolinian faunal region, intergrading through the Transition region northward with *hudsonica* and southward through the Austrariparian into *vaga* of southern Florida.

Color.—Much lighter than *hudsonica*. Above (from a specimen taken at Liberty Hill, Conn., No. 4252, ad. ♂, Nov. 19, 1895, collection of E. A. and O. Bangs*), dark vandyke brown, tipped on upper head, neck and shoulders with wood brown, darkening posteriorly. Upper feet and limbs dark bistre. Below, from lower breast to end of tail, between Prout's brown and broccoli brown. Head, neck and breast, including ears, below a line connecting nose, upper eyelid, upper ear and upper base of fore leg, grayish wood brown, lightest on head, darkening posteriorly to color (*l. c.*) of breast. The average Carolinian winter specimens from Maryland southward are somewhat lighter and some are Prout's brown above, the wood brown of lower head and neck becoming a pale grayish buff.

Anatomical Characters.—Size, smallest of the *hudsonica* subspecies. Inferior webs of feet and interspace between callosities of manus, sparsely haired. Hind foot with claw about 120 mm. Total length rarely exceeding 1100 mm. Skull relatively small, with very large teeth, and weak postorbital processes. In other respects like the *hudsonica* type.

Measurements.—See tables.

Remarks.—The relations of this subspecies to northern *hudsonica* on the one hand and to the southern *vaga* on the other are rather peculiar. It is without question a nearer ally to *hudsonica* than *vaga* in the territory between Connecticut and South Carolina, but, as Mr. Bangs has implied in his remarks on *vaga*, there is a tendency in the Georgia (and we may infer in the South Carolina) otter to the large size and peculiar

* This specimen comes from the northern edge of the Carolinian region. No equally good skins from more southern localities being available, it is used as typical of the Carolinian race. It corresponds closely to two fine 1897-8 winter pelts of Maryland otters, examined through the courtesy of Mr. S. E. Shoyer, of Philadelphia.

skull and color characters of the south Florida animal. There is so much evidence of the intergradation of *lataxina* both north and south that the specific separation of *vaga* from it is not permissible. On the other hand it is impossible to ignore the decided racial differences of the Carolinian otter from the Hudsonian type.

Cuvier's original description of *lataxina* gives "Caroline du Sud" as the locality where the type was taken; it is, therefore, permissible to restrict this name to the Carolinian form as typified in the otters found in the Carolinian lowlands of the eastern United States from south of the "Transition Zone" of Dr. C. Hart Merriam, as far as middle South Carolina, Alabama and Mississippi, where it merges into *vaga* of the Gulf or southern "Austroriparian Realm" of Dr. J. A. Allen.

I know of no restricted synonyms of *lataxina*. Dr. Coues quotes in his *Fur-bearing Animals* a "*Latax lataxina* Gray, *Ann. Mag. N. H.*, I, 1837, p. 119." The work referred to contains no such name. Cuvier's description of *lataxina* gives its color as "dark blackish brown, a little paler beneath. Cheeks, temples, lips, chin and throat pale brownish gray, and under side of tail grayish brown, the hair tips reddish." He compares the skull of *lataxina* with his *Lutra enudris*, "Loutre de Guianæ" of the preceding page and remarks on the "straight line, even concave or depressed," joining the nasals and occiput. This is significant, as one of the peculiarities separating *vaga* from *lataxina* and *hudsonica* is the *convexity* of the frontal plane in the former.

Specimens Examined.—Connecticut, Liberty Hill, 1 skin with skull; Pennsylvania, Clinton county, 2 mounted specimens; Monroe county, 3 skulls; New Jersey, Tuckerton, 1 skull; Mickleton, 2 disarticulated skeletons; Maryland, 2 fresh cased winter furs; North Carolina, Raleigh, 2 skulls.

FLORIDA OTTER. *Lutra hudsonica vaga* Bangs.

Plate XXV; Fig. 2.

Lutra hudsonica vaga Bangs, *Proc. Bos. Soc. Nat. Hist.*, XXVIII, 1898, p. 224.

Type Locality.—Micco, Brevard county, Florida.

Geographic Distribution.—Florida, southeastern Georgia and the Gulf regions of Alabama, Mississippi and Louisiana, intergrading (?) northwardly into *lataxina*.

Color.—Dark; less black than *hudsonica*, darker and redder than *lataxina*. Breast and belly nearly unicolor with back. Paler area of head and neck, scarcely reaching breast. Above and below, dark, rich chestnut, scarcely paler on belly. Lower head and anterior throat below line from nose to and behind ears, strongly tipped anteriorly with tawny Isabella color darkening to raw umber on throat, the underfur darker than overfur, instead of lighter as in *lataxina*.

Anatomical Characters.—Size, large. Tail relatively long (*vide* Bangs). Inferior webs of feet and interspace of palms nearly naked. Hind foot with claw reaching maximum (No. 4998 Bangs Coll., yg. ad. ♂, Citronelle, Florida) of 130 mm. Total length (maximum of No. 4998, *l. c.*, 1285 mm.) exceeding 1200 mm. Skull large, teeth relatively small, not crowded longitudinally. Postorbital neck of frontals long and narrow, suddenly constricted at base. Frontal plane strongly upraised above a line connecting occipital crest with base of nasals and above the level of postorbital processes. Mastoid width nearly equaling the zygomatic width in very old specimens, in young adult skulls the mastoid width is the greater. Wings of mastoid processes strongly developed and flattened laterally. Audital bullæ as in *hudsonica* and *lataxina*; well developed, tumid at basioccipital margins. Postorbital processes relatively weak and slender. Underfur short, sparse.

Measurements.—See tables.

Remarks.—This subspecies just described by Mr. Bangs in his most valuable paper on Florida and Georgia mammals is, as already noticed, quite different from *lataxina*, its nearest geographic ally. In color it comes nearer *hudsonica* intermediates from New England. In size and color and lack of hair on the webs and palms it shows approach to the remote *pacifica*, but its peculiar long-waisted and broad-based skull distinguishes it from all other American forms except, perhaps, those of the northern Central American and South American otters which I have examined. The yellowish and reddish shades of south Florida *vaga* suggest affinity with what we find published of the characters of the otters of the Caribbean coasts. In essential respects Mr. Bangs' diagnosis of this animal is very good. He, however, used the skull of a young adult male for cranial comparisons, and while it is true that the ratio of the mastoid to the zygomatic width is much greater in *vaga* than *hudsonica* it is not as great as would appear by Mr. Bangs' figure. In crania of old adult *vaga* in my collection the mastoid and zygomatic widths are about equal, the latter slightly wider. In *hudsonica*, however, the excess of zygomatic width and slight development of the mastoid wings is marked.

Specimens Examined.—Florida, Tarpon Springs, 1 adult pelt, 3 young skins with skulls and 2 extra skulls; Salt Run, St. John's river, 1 skull.

PACIFIC OTTER. *Lutra hudsonica pacifica*, subsp. nov.

Plate XXIV; Fig. 3. Plate XXV; Figs. 1 and 3.

Lutra paranensis and *aterrima* Thomas, *P. Z. S.*, *l. c.*, p. 199; Trouessart, *Catal. Mamm.*, 1897, pp. 286, 287 (not of Pallas, *Zoogr. Ross. Asiat.*, 1811, p. 81).

Lutra californica Baird, *Mamm. N. Amer.*, 1857, p. 187 (not of Gray, *Mag. Nat. Hist.*, I, 1835, p. 580, which is *L. felina*; see Thomas, *l. c.*, p. 198).

Type Locality.—Lake Kichelos, Kittitass county, Washington; altitude about 8000 feet. Type No. 616, yg. ad. ♂, in the collection of S. N. Rhoads; collected in fall or winter* of 1892-'93, by Allan Rupert.

Geographic Distribution.—Pacific slope of North America, from Alaska to California.

Color.—Of type: Lighter than *hudsonica*, with a browner cast, approaching nearly to *lataxina*. Average of coast specimens from Puget Sound northward, ruddy seal brown, sometimes very dark in Alaskan coast specimens. Lower parts from breast to end of tail much lighter (Mars-brown) than back. Ventral region conspicuously lighter. Lower head, neck and breast very pale wood brown, almost dirty gray.

Anatomical Characters.—Size, very large.† Tail normal. Inferior webs of feet and palmar interspaces nearly naked. Hind foot not recorded in type, the calcaneum missing; no measurements of other specimens available. Skull largest of the North American otters (reaching a maximum of 119 mm. in occipito-nasal length and 83 mm. in zygomatic expanse in an Alaskan coast example); teeth relatively weak, less crowded longitudinally than in *hudsonica*. Interorbital width relatively very great, nearly 1½ times postorbital constriction; postorbital processes long and stout. Mastoid and zygomatic proportions as in *hudsonica*. Audital bullæ remarkably flattened.

Measurements.—See tables.

Remarks.—The type specimen, though taken in the mountains and not fully mature, is large and has a skull which would have, perhaps, eventually equaled the maximum size recorded above for an Alaskan specimen of much greater age. A very old female skull from the vicinity of Puget Sound confirms fully the diagnostic characters of *pacifica* as given.

In treating of the otters of the Pacific slope of America we are confronted with two nominal species to which they have been doubtfully referred by authors. In point of time the first to be considered is the *Viverra aterrima* of Pallas,‡ described from a hunter's skin, lacking skull and feet, taken in northeast Siberia, "between the Uth and Amur rivers." Schrenck and Middendorff listed this animal in their works on Siberian Zoölogy with the remark that they were unable to verify its existence or clear up the mystery of its strange characters as given by Pallas. Mr. Thomas (*P. Z. S., l. c.*, p. 199) queries, on the basis of a mistaken suggestion of Dr. Coues, whether it may

* The season of capture was not recorded, but the pelt indicates that it was taken in full winter fur.

† I have no measurements of Alaskan otters, but judging by the great size of the skulls from there they must greatly exceed any known species of *Lutra*. On the basis of the skull they must attain a maximum length of over 1400 millimeters.

‡ *Zoog. Rosso. Asiat., l. c.*

not prove to be the same as the so-called *Lutra paranensis* Rengg. which he assumed might occur throughout the whole Pacific coast regions of America. The close relationship of our Pacific coast otters to *hudsonica* will effectually remove them from any complication with *paranensis*, but as regards *aterrima* we must devote sufficient space to show the impossibility of referring the Alaskan land otter to that animal, as Trouessart has lately done.*

A careful study of Pallas' original description, together with the fact that no later author or explorer has been able to explain or rediscover the animal, convinces me that it is either unidentifiable or will prove not to belong to the *Lutrinæ* but to the *Mustelinæ*. Pallas states it to be intermediate in size between the European otter and the European mink. He states the length of the skin to be 19 inches, 3 lines, and of the tail 5 inches with a *brush* of $1\frac{1}{2}$ inches! The color of the animal is said to be very black and shining, except the sides of the head between the eyes and ears, which change from black to "subrufescent." The absurdity of applying such a description to the animal which I have named *pacifica*, or, indeed, to any member of the genus *Lutra*, is certainly evident. So far as any animal now known to zoölogists is concerned, the *Viverra aterrima* of Pallas should be consigned to oblivion.

Another name which has given trouble to those who had to deal with the Pacific coast otter is the *Lutra californica* of Gray. Fortunately, Mr. Thomas has effectually exposed the history and at the same time the inapplicability of that name to a North American animal of the *hudsonica* type. He has shown in his paper in the *Proceedings of the Zoölogical Society* (l. c., p. 198) that Gray's type of *californica* did not come from California, but most likely from Patagonia, in which case he makes it a synonym of *Lutra felina* Molina.

Specimens Examined.—Washington, near Tacoma, 3 skulls; Lake Kichelos, 1 skin with skull, 1 skull; Oregon, 1 skull; British Columbia, Sumas, 1 skull; Alaska (coast?), 3 skulls; Kodiak Island, 2 skulls; Mission, 1 skull; Queraquina† Island, 1 skull.

SONORAN OTTER. *Lutra hudsonica sonora*, subsp. nov.

Lutra canadensis Mearns, *Bull. Am. Mus. Nat. Hist.*, III, 1891, pp. 253–256.

Type Locality.—Montezuma Well, Beaver creek, Yavapai county, Arizona. Type, ad. ♀, No. $\frac{3712}{809}$ in the collection of the American Museum of Natural History. Collected December 26, 1886, by Dr. Edgar A. Mearns.

* *Catalogus Mammalium*, l. c.

† It is conjectured that this skull came from the North Pacific. It has Capt. T. J. Turner's name on it. I cannot find an island of this name on the maps.

Geographic Distribution.—Arid southern interior of North America, from Mexico, probably to Wyoming.

Color.—Of type, *fide* Mearns, *l. c.*: "Above dark brown, without reddish tinge; this color changing gradually to a light grayish brown below, being palest (almost whitish) upon the sides of the head below the level of the eyes and upon the under side of the head and neck as far back as the fore limbs. . . . The long hairs of the lighter portions of the body are pointed with yellowish gray and upon the upper surface of the head and neck the tips of the hairs are yellowish brown, giving a paler cast to that part of the dorsum."

Anatomical Characters.—Size, large, with a very long hind foot, the body length measurements exceeding those of any other specimen of North American otter examined or recorded.* Webs of feet not densely haired beneath. Hind foot, 145 mm. Total length reaching 1300 mm. Skull—size, large, nearly as great as in largest Alaskan *pacifica*, but small for the great relative length of body, "less massive, broader, with more evenly rounded zygomatic arches and with the brain case more convex or bulging in its outlines." "Arizona skulls differ from all others in the slender, attenuated postorbital processes and in the greater height of the lower jaw from angle to condyle, or to summit of coronoid process. From its geographically near neighbor, *L. felina* of Central America, it presents many cranial and dental differences; in fact, skulls of the latter are so very distinct [in their inferior concavity, frontal depression, short muzzle, narrow postorbital constriction and absence of the heel in front of the antero-internal cusp of the last upper molar] from any known specimens from North America, north of Mexico, as to be distinguishable from them at a glance."

Measurements.—Of type: "Total length, 1300 mm.; head and body (measured from tip of nose to anus), 815 mm.; tail measured from anus to end of vertebræ, 472 mm. . . . ear, height above crown, 15 mm." No skull measurements given.

Remarks.—I have accepted Dr. Mearns' very full and satisfactory diagnosis of the Arizona otter, given in the *Bulletin of the American Museum of Natural History*, as conclusive evidence of the existence of a recognizable race in arid interior America, south of Montana. Its great size and light color together form a combination not found in any other known or named otter.

It has been thought unnecessary to examine the type, as, owing to the author's removal from Philadelphia during the completion of this paper, such an examination would have caused a greater risk to the type specimens than the facts warranted.

* The great size of the type, as compared with an adult male also recorded by Dr. Mearns from Arizona, indicates that the sex of the type may have been wrongly determined. If correct, the size to be expected of a full-grown male *sonora* would be extraordinary.

NEWFOUNDLAND OTTER. *Lutra degener* Bangs.

Plate XXIV; Fig. 5.

Lutra degener Bangs, *Proc. Biol. Soc. Wash.*, XII, 1898, p. 35.*Type Locality*.—Bay St. George, Newfoundland.*Geographic Distribution*.—Confined to Newfoundland (?).*Color*.—Of type, ad. ♂, taken April 22, 1897: Above, black with seal brown reflections. Ears, seal brown. Lower head and neck areas grayish wood brown, becoming seal brown on breast; the remainder of lower parts nearly as dark as back. Tail unicolor. Feet seal brown and densely haired on under side of webs and palmar interspaces.*Anatomical Characters*.—Size, much smaller than any of the *hudsonica* group. Hind foot small, with claw averaging about 112 mm.* long in the two specimens examined. Total length about 1000 mm. Tail relatively short. Skull very small, narrowed, weak and fragile; the brain case wide anteriorly; the frontal and interorbital widths narrow and the postorbital processes weak and slender, strongly grooved on their superior face. Sagittal crest not developed even in old specimens. Interorbital constriction about equal to postorbital constriction. Teeth weak, with normal cuspidation. Audital bullæ normal.*Measurements*.—See tables.*Remarks*.—The type specimens of *degener*, so generously loaned to me by Mr. Bangs, when compared with the large series used in the preparation of this paper, convince me that this depauperate insular form has no intercourse with the larger typical *hudsonica* of Labrador and New Brunswick. A skull from Grand river, Labrador, shows no approach to the *degener* type, and another from Okak, Labrador, agrees in the same differences. A young adult skull and skin of *hudsonica* from Nova Scotia, and an adult summer skin from New Brunswick, show that the maritime otter of the mainland sometimes attains a size nearly one-third larger than the largest known specimens of old, adult *degener*.*Specimens Examined*.—Newfoundland, Bay St. George, 2 skins with skulls, 1 extra skull.

THE FISHERS OF NORTH AMERICA.

Apology must be made for the inferior series of skins and skulls which form the basis of the subjoined remarks on the Pekan. They serve, however, to elucidate some

* The collector's measurement of the hind foot of type is given on label as "126 mm." This is certainly incorrect, as the length determinable by feeling the calcaneum in the dry skin could not have exceeded 115 mm. This accords with the small size of the hind foot and the length of other specimens of *degener*,

questions sure to be soon brought up in the active advance of monographic work in American mammalogy.

The synonymy of Pennant's Fisher has already been discussed under *Lutra hudsonica*, and I have there given reasons for my adoption of the plate-name *canadensis* of Schreber as having priority over the long-accepted name *pennanti* of Erxleben for this animal.

PENNANT'S FISHER. *Mustela canadensis* Schreber.

Mustela canadensis Schreber, *Saugt.*, III, p. 492, Pl. CXXIV. Text published in 1777, plate in 1776 (*fide* Sherborn).

Mustela pennantii Erxleben, *Syst. An.*, 1777, p. 470.

Mustela melanorhyncha Boddaert, *Elench. An.*, 1784, p. 88.

Viverra piscator Shaw, *Gen. Zoöl.*, I, 1800, p. 414.

Mustela nigra Turton, *ed. Linn. Syst. Nat.*, I, 1802, p. 60.

Mustela godmani Fischer, *Syn. Mamm.*, 1829, p. 217.

Type Locality.—"New York and Pennsylvania," Pennant.

Geographic Distribution.—Northern North America, east of the Cascade mountains, from the northern limit of trees to Colorado and North Carolina in the mountains. Intergrading on the Pacific slope into subspecies *pacifica*, and probably in the southern Rocky mountain region into a paler race. Probably represented in the Hudsonian faunal region by a subspecies.*

Color.—From an adult, male, winter specimen taken near Lancaster, Pa., March 11, 1896, and in the possession of Dr. M. W. Raub, of that city, who furnished the description: "Head and one-half of the length of body, gray and black mixed, gray predominating; throat darkest, with snout from tip to line of eyes dark brown. The hinder half of body gradually darkens into a deep chocolate color until it reaches the tail, which is almost black with a tip entirely black. Hind legs and tail, viewed at a distance of six feet, look very dark, almost pure black. The fore legs are black but not so deep. Tips of ears, darkest."

Two specimens from the Bangs collection, one from Moosehead lake, Maine, the other from Idaho county, Idaho, seem to answer closely the above description. The light upper and forward portions of body are a grizzled grayish brown, the long hairs black tipped. The basal half of hairs of anterior back are hair brown. I can discover no color characters to separate the Idaho specimen from the one from Maine, nor do the skulls indicate any reliable differences. The Maine skin (of an animal two-thirds grown)

* Typical *canadensis* must be restricted to the Alleghenian form.

has white patches on lower fore leg, breast and vent, and an immature specimen of *pacifica* has white spots on throat, arm-pits and vent. The four adult specimens examined are not thus pied. Dr. Coues, in his *Fur-bearing Animals*, says that the fisher is an exception to the marten, mink and weasel in not having these patches. They may disappear with age in the fisher, but they do not in the other species.

Anatomical Characters.—Size, smaller than subspecies *pacifica*. Skull small; nasals relatively short, less elongate at basal apex. Posterior upper molar relatively small, its inner lobe not greatly developed longitudinally so as to only slightly exceed the breadth of outer lobe; neck of crown of same tooth but slightly constricted.

Measurements.—Of Dr. Raub's Pennsylvania specimen, old ad. ♂, *l. c.*: Total length, from end of nose to end of tail hairs, 965 mm.; tail vertebræ, 318 mm.; hind foot, 115 mm.; ear from crown, 27 mm. A mounted specimen, No. 507, Academy Natural Sciences, adult ♂, from "Pennsylvania," has a total length of 1000 mm., with tail (minus brush), 390 mm., and hind foot, 112 mm., taken from the dry mount. The Idaho specimen, No. 6964, young adult ♂, coll. of E. A. and O. Bangs, is 978 mm. long, with tail, 369 mm., and hind foot, 117 mm. Skull of No. 7437, yg. ad. ♂, Greenville, Me., total length, 117 mm.; zygomatic width, 63 mm.; mastoid width, 54 mm.; mesial nasal length, 22 mm.

Remarks.—The characters of the Pennsylvania fishers above enumerated, so far as they are based on reliable measurements and color diagnoses, may be considered as representing typical *canadensis*, based on Pennant's original notice of the animal. Whether a series of Alleghenian fishers will show the Hudsonian animal to be separable is an interesting question probably to be decided in the affirmative. The Idaho and Maine specimens examined, though not contrasted by me with Dr. Raub's specimen, must be very close to it. No skulls of Pennsylvania fishers have been examined, but the close resemblance of the Idaho skull to those from Maine, as indeed to *pacifica* also, strongly indicates that no cranial differences exist between the east American fishers of the north and south. The "saturated" color characters of *pacifica* are alone sufficient to distinguish it from all fishers found east of the Cascades.

Specimens Examined.—Pennsylvania, 1 mounted specimen (*fide* Dr. Raub, 1 mounted specimen); Maine, Mooseland lake, 1 skin with skull; Greenville, 2 skulls; Lincoln, 1 skull; Idaho, Idaho county, 1 skin with skull. Other specimens from eastern North America, 1 mounted, 2 old ad. skulls.

PACIFIC FISHER. *Mustela canadensis pacifica*, subsp. nov.

Type Locality.—Lake Kichelos, Kittitass county, Washington; altitude about 8000

feet. Type, No. 1074, old ad. ♀, in the collection of S. N. Rhoads; collected in the fall or winter of 1892-'93, by Allan Rupert.*

Geographic Distribution.—Pacific slope of America, from Alaska to California.

Color.—Above, from between eyes to middle back, grizzled, grayish ochraceous heavily lined with black, becoming hazel black on hind back and dark black on rump, thighs and tail. Whole head, behind eyes clove brown basally, strongly grizzled with dirty white. Snout to eyes blackish seal brown. Chin, throat, breast and belly between dark chestnut and hazel, obscured with black. Legs and feet black, the fore legs showing the vandyke brown bases of hairs. Basal half of hairs of anterior back are Prout's brown as contrasted with the hair brown of *canadensis*.

Anatomical Characters.—Size, large, skull very large, with relatively long nasals. Posterior upper molar large, with spreading inner lobe much wider longitudinally than outer section of same tooth; the crown suddenly constricted at the middle.

Measurements.—Of type from relaxed skin: Total length, 1090 mm.; tail, 350 mm. without brush; hind foot not determinable, as the bones are missing. Measurements of a specimen two-thirds grown, No. 295, coll. S. N. Rhoads, from near Tacoma, Wash.: Total length (relaxed skin), 970 mm.; tail, 400 mm.; hind foot, 112 mm.; ear from crown, 21 mm. Skull of type: Total length from hinder end of sagittal crest to front end of premaxillæ, 125 mm.; zygomatic expansion, 73 mm.; mastoid expansion, 54 mm.; interorbital constriction, 28.5 mm.; postorbital constriction, 20 mm.; mesial length of nasals, 27 mm.

Remarks.—The dimensions of the type skull, when we consider it was from a female, show that the fishers of the Cascade mountains attain a much greater size than those of the Appalachian chain. Young adult skulls of the same age from western Washington and Maine show the same distinctions. The younger specimen from Tacoma, while approaching nearer to Idaho and Maine specimens in grayer color, is very much darker than they, the difference in shade between the anterior and posterior dorsal areas of the former being slight, while in the latter it is striking. The tawny suffusion so deeply marked in the type of *pacifica* and which separates it at a glance from *canadensis* is also noticeable in the Tacoma specimen.

Specimens Examined.—Washington, Lake Kichelos, 1 skin with skull, 2 skulls; near Tacoma, 1 skin, 1 skull; British Columbia, Sumas, 1 skull.

* Mr. Rupert, whose business is hunting and trapping, first sent me the fresh skull of a very old ♀ fisher, which was entered in my catalogue as No. 621. I wrote him immediately that I would like to have the pelt belonging thereto, and in a later shipment the skin, which forms the type of *pacifica*, was sent on without label. As it is also from a female and a very old animal, I consider the skin and skull as belonging to the same individual.

Skull Measurements of North American Otters (in millimeters)

Collection.	Catalogue Number.	Sex.	Locality.	Species.	Length from posterior apex of occiput to anterior end of premaxilla.	Zygomatic expansion.	Mastoid expansion.	Interorbital constriction.	Postorbital constriction.	Expanse of post-orbital processes.	Length of postorbital frontal neck.	Remarks.
E. A. and O. Bangs	5638	yg. ad. ♂	Nova Scotia, Annapolis	<i>L. hudsonica</i> ("Lacép," Desm.)	113.5	72	68	27.7	23	35	15	Large, coast form.
do.	7431	old ad.	Labrador, Okak	do.		74.5	67	23	19	35	13.5	Coast form.
Acad. N. Sci. Phila.	3150	old ad.	Labrador, Grand River	do.	105	72.5	65	20.8	20	29	10.5	Inland form.
Smithsonian Inst.	21483	old ad.	Alaska, Tanana River	do.	102	72	63.5	24	18	32	12.5	Inland form.
E. A. and O. Bangs	4238	old ad. ♂	Maine, Bucksport	do.	109	73.5	66	25.5	21.5	37	14	Coast form.
do.	4188	old ad. ♂	Massachusetts, Canton	do.	112	76	69	26	22	38	15.	Intermediate.
Acad. N. Sci. Phila.	3569	old ad.	Pennsylvania, Monroe Co.	<i>L. h. lataxina</i> (F. Cuv.)	100	69.5	65	22.8	20	31	13	Inland intern., prob. ♀.
S. N. Rhoads	1840	yg. ad.	do.	do.	104.5	68	61	21.5	19	28.6	12	Probably ♂.
do.	1565	yg. ad.	New Jersey, Truckerton	do.	104	70	63.5	24.5	23	33.5	11	
do.	3896	yg. ad.	New Jersey, Mickleton	do.	107	70	63	23			12	
E. A. and O. Bangs	3537	old ad. ♂	North Carolina, Raleigh	do.	104	71	62	22	22	33	13.5	
do.	3538	yg. ad. ♀	do.	do.	103	65.5	61	21.5	21	30.5	11	
do.	5749	yg. ad. ♂	Florida, Mico	<i>L. h. vaga</i> Bangs	108	71	71.2	24	18.6	35	16	Type (<i>fide</i> Bangs).
do.	4995	ad. ♀	Florida, Roseland	do.	[101]	70.3	67	21.8	17.8	30		(<i>fide</i> Bangs.)
Wagner Inst., Phila	—	ad.	Florida, St. John's Riv., Volusia Co.	do.	105	72	67	24	22	34	18.2	
S. N. Rhoads	1580	old ad. ♂	Florida, Tarpon Springs	do.	116	79	76.5	27	20.5	39.5	20	
do.	616	yg. ad. ♂	Washington, L. Kichelos	<i>L. h. pacifica</i> Rhoads	115.5	72.5	69	25	20	36.5	12	Type.
do.	303	old ad. ♀	Washington, near Tacoma	do.	110.5	77	70	29	21.5	43	16	
Smithsonian Inst.	8686	old ad.	Alaska (coast?)	do.	113.5	74.5	70.4	27.3	24	41	16	Col. by Dr. T. T. Minor.
do.	8687	old ad.	do.	do.	119	83	76	34	25	49	14	do.
do.	8688	old ad.	do.	do.	110	78	73	27	18	41.5	15	
E. A. and O. Bangs	6965	yg. ? ad. ♂	Newfoundland, Bay St. George	<i>L. degener</i> Bangs	101	66	60	22	19.5	32.5	11.5	Type.
do.	6966	old ad. ♀	do.	do.	[98]	70	63	22.8	19.4	33.6		Topotype (<i>fide</i> Bangs).
do.	3755	yg. ad. ♀	do.	do.	93	64	56	19	18.8	25.8	10	Topotype.

Body Measurements of North American Otters (in millimeters).

Collection.	Catalogue Number.	Sex.	Locality.	Species.	Total Length.	Tail Vertebrae.	Blind Foot.	Remarks.
E. A. and O. Bangs	5638	yg. ad. ♂	Nova Scotia, Annapolis	<i>L. hudsonica</i> ("Lacép., Desm.)	1090	415	[123]	Large, coast form.
do.	46	?	New Brunswick, Restigouche Riv.	do.	1190	393	115	Meas. taken from stuffed skin.
do.	4189	ad. ♂	Massachusetts, Kingston	do.	1168	457	124	Intermediate.
do.	4190	ad. ♀	Maine, Upton (L. Umbagog)	do.	1065	406	114	Inland type.
Acad. N. Sci. Phila.	3360	im. ♂	Pennsylvania, Clinton Co.	<i>L. h. lataxina</i> (F. Cuv.)	1016	360	115	Inland type, mounted spec'n.
E. A. and O. Bangs	4252	yg. ad. ♂	Connecticut, Liberty Hill	do.	1093	410	127	Intermediate.
H. H. and C. S. Brimley	451	ad. ♀	North Carolina, Raleigh	do.	1066	368		Weight, 15 lbs.
do.	453	ad. ♂	do.	do.	1144	445		Weight, 17 lbs.
do.	—	ad. ♂	do.	do.	1130			Weight, 16 lbs.
E. A. and O. Bangs	4995	ad. ♀	Florida, Roseland	<i>L. h. vaga</i> Bangs	1100	400	110	
do.	4998	yg. ad. ♂	Florida, Citronelle	do.	1255	487	130	
S. N. Rhoads	616	yg. ad. ♂	Washington, Lake Kichelos	<i>L. h. pacifica</i> Rhoads	1117	419	128?	Type.
do.	302	yg. ad. ♂	Washington, near Tacoma	do.	1092	368	120	Meas. from ligamentous skeleton.
Amer. Mus. Nat. Hist.	3712 — 309	ad. ♀	Beaver Creek, Yavapai Co., Arizona	<i>L. h. sonora</i> Rhoads	1300	472	146	Type. Weight, 19 $\frac{1}{8}$ lbs.
E. A. and O. Bangs	6965	ad. ♂	Newfoundland, B. St. George	<i>L. degener</i> Bangs	998	358	[115]	Type.
do.	6966	ad. ♀	do.	do.	990	352	109	Topotype.

EXPLANATION OF PLATES.

Plates XXI and XXII.

(Scale slightly less than two-thirds natural size.)

- Figs. 1 and 1. *Castor canadensis pacificus* Rhoads. Topotype; No. 1865, col. of S. N. Rhoads; old adult ♂, from Lake Kichelos, Kittitass county, Wash. Superior and inferior, vertical aspects of same skull.
- Figs. 2 and 2. *Castor canadensis frondator* Mearns. No. 32, col. of E. A. and O. Bangs; young adult ♀, from Red Lodge, Mont. Superior and inferior, vertical aspects of same skull.
- Figs. 3 and 3. *Castor canadensis* Kuhl. No. 31, col. of E. A. and O. Bangs; old adult (probably ♂), from New Brunswick. Superior and inferior, vertical aspects of same skull.

Plate XXIII.

(Scale four-fifths natural size.)

- Figs. 1 and 2. *Castor canadensis carolinensis* Rhoads. Type; No. Z. 609, col. of State Museum of N. Carolina; old adult ♂, from Dan river near Danbury, Stokes county, N. Carolina. Superior and inferior, vertical aspects of same skull.

Plate XXIV.

(Scale six-sevenths natural size.)

- Fig. 1. *Lutra hudsonica* ("Lacépède," Desmarest). No. 4188, col. of E. A. and O. Bangs; old adult ♂, from Canton, Mass. Superior, vertical aspect of skull.
- Fig. 2. *Lutra hudsonica* ("Lacépède," Desmarest). No. 1201, col. of E. A. and O. Bangs, old adult ♂, from Westford, Mass. Inferior aspect of skull.
- Fig. 3. *Lutra hudsonica pacifica* Rhoads. No. 8686, col. of Smithsonian Institution; old adult, from (the coast of?) Alaska. Inferior aspect of skull.
- Fig. 4. *Lutra hudsonica lataxina* (F. Cuvier). No. 3537, col. of E. A. and O. Bangs; old adult ♂, from Raleigh, N. Carolina. Superior, vertical aspect of skull.
- Fig. 5. *Lutra degener* Bangs. Type; No. 6965, col. of E. A. and O. Bangs; adult ♂, from Bay St. George, Newfoundland. Superior, vertical aspect of skull.

Plate XXV.

(Scale slightly less than five-sixths natural size.)

- Fig. 1. *Lutra hudsonica pacifica* Rhoads. No. 8687, col. of Smithsonian Institution; old adult (probably ♂), from (the coast of?) Alaska. Superior, vertical aspect of skull.
- Fig. 2. *Lutra hudsonica vaga* Bangs. No. 1580, col. of S. N. Rhoads; old adult ♂, from Tarpon Springs, Fla. Superior, vertical aspect of skull.
- Fig. 3. *Lutra hudsonica pacifica* Rhoads. No. 303, col. of S. N. Rhoads; old adult ♀, from Tacoma, Wash. Superior, vertical aspect of skull.



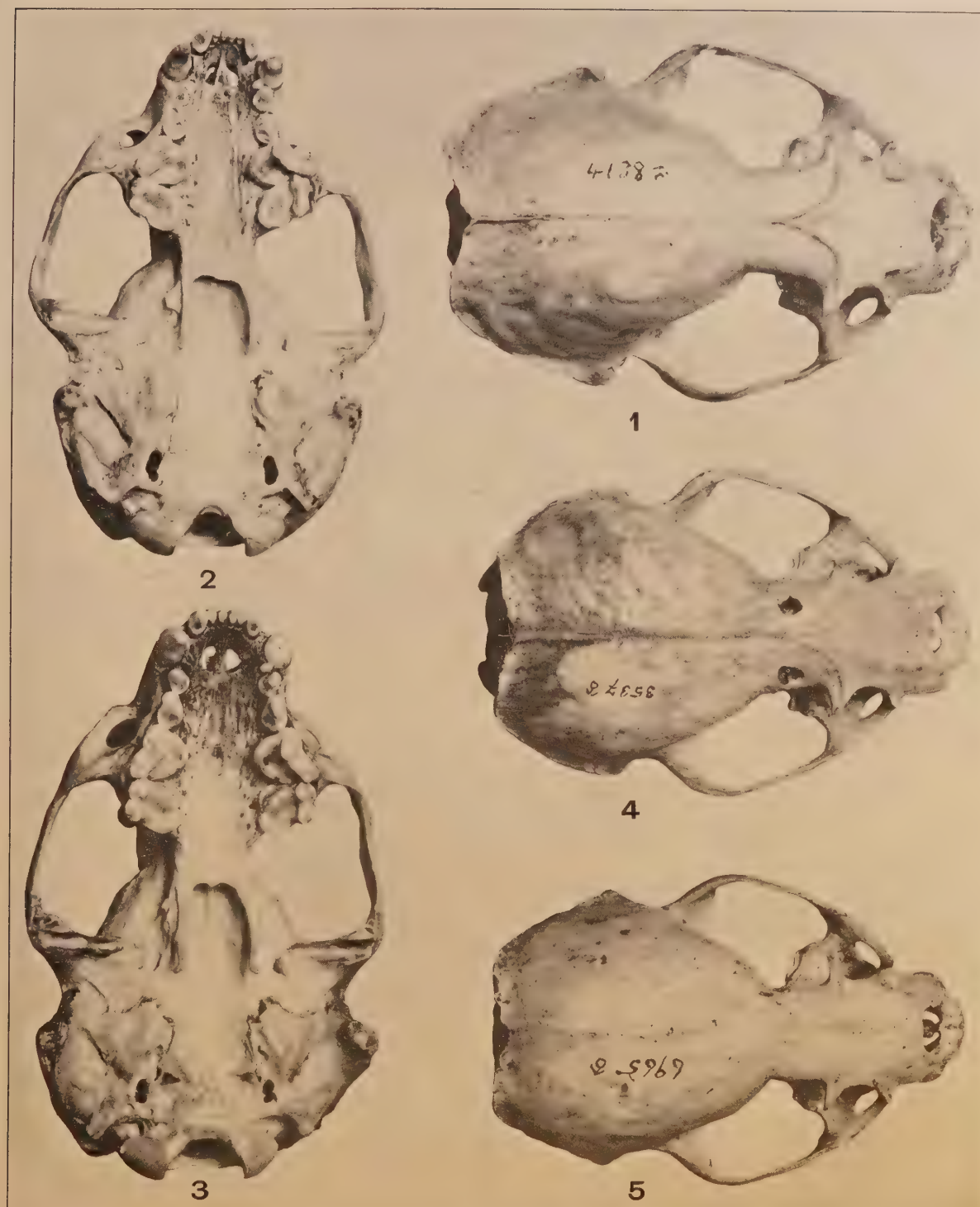
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VOLUME XX.—NEW SERIES.

PART I.

ARTICLE I.—*The History of the Pelycosauria, with a Description of the Genus Dimetrodon, Cope.* By
G. Baur and E. O. Case.

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TRANSACTIONS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY.

ARTICLE I.

THE HISTORY OF THE PELYCOSAURIA, WITH A DESCRIPTION OF THE GENUS DIMETRODON, COPE.*

BY G. BAUR AND E. C. CASE.

Read before the American Philosophical Society, March 3, 1899.

HISTORICAL.

The first remains of Permian Reptiles in the United States were described by Prof. Cope¹ in 1875 from near Danville, Vermillion county, in eastern Illinois. It was left undecided whether the strata from which the fossils came belonged to the Triassic or the Permian. The vertebrate remains are unaccompanied by invertebrate fossils, but the invertebrate remains of the region are all Carboniferous forms. Mr. Gurley, of Danville, the discoverer of the fossils, considers that the vertebrate remains came from deposits in the bed of an ancient river of the Permian time which cut through the underlying Carboniferous rocks. This, if true, explains the puzzling feature of these typically Permian forms occurring on the same level with the Carboniferous invertebrates.

The genus and species *Clepsydrops collettii* Cope was established, based on cervicals, including the axis, dorsal and caudal vertebræ; besides proximal ends of ribs, an

*PREFATORY NOTE.—The unfortunate death of Dr. Baur left the manuscript of this article in the hands of the junior author in an unfinished condition, and he has attempted to complete it with as little change from the original portion written by Dr. Baur as possible. The historical part, with the exception of the Russian and the Bohemian forms, and a portion of the African forms, was the work of Dr. Baur. The description of the skeleton was the work of the junior author, with the advice of Dr. Baur.

astragalus, considered first as a coracoid bone, and some phalanges, which were provisionally referred to the same genus. The vertebræ are deeply biconcave, and notochordal. There are no processes on the centra, but a small capitular, articular face is present on the anterior articular edge of two of the dorsals. The dorsal vertebræ have the sides somewhat contracted; in one specimen the inferior face rounded, in another it is longitudinally acute. The diapophysis does not project far beyond the base of the neural arch, and is compressed. The caudals are elongate. Then follow remarks about the ribs, astragalus and phalanges. That these remains belonged to a small animal is indicated by the size of the vertebræ:

	M.		M.
Length of centrum of sharp keeled dorsal.....	0.014	of rounded dorsal.....	0.012
Depth behind.....	0.012		0.011
Width behind.....	0.012		0.0105.

Cope says of *Clepsydropus*: "This genus is more typically Rhynchocephalian than *Cricotus*," not knowing at that time that *Cricotus* is one of the *Stegocephali* (*Labyrinthodonta*).

The next communication was made by Cope² in 1877. *Clepsydropus* is now placed definitely among the *Rhynchocephalia*. *Clepsydropus collettii* Cope is said to be the most abundant land vertebrate of the formation, being represented in all the collections, sometimes by portions of individuals of double the size of the type. There is a single occipital condyle. Two new species of *Clepsydropus* are described, *C. vinslovii* and *C. pedunculatus*.

C. vinslovii Cope is based on a third cervical vertebræ, and probably represented by other vertebræ. *C. pedunculatus* Cope is established on a third cervical and another, apparently dorsal one. This species is said to be characterized by the stronger diapophyses.

Teeth are described, Species No. 4, p. 56, and are referred to *Clepsydropus collettii*. The horizon from which the fossils came is now considered as Permian, and is named the *Clepsydropus shale*.

In the same year the discovery of Permian Reptiles in Texas was announced by Cope,³ and other remains from Illinois are described. *Lysorophus tricarinatus* Cope is named and described. "Vertebræ amphicoelian, perforated by the foramen chordæ dorsalis. Neural arch freely articulated to the centrum. Floor of neural canal deeply excavated. No processes nor costal articulations on the centrum, which is excavated by longitudinal fossæ. Centrum not shortened." From near Danville, Illinois. Based on two centra and a portion of a third. Another new genus and species is based on teeth: *Archæobelus vellicatus*, "Species No. 4," Cope, *Proc. Amer. Philos. Soc.*, 1877, p. 192.

A new species of *Clepsydrops*, *C. limbatus*, is described from Texas. It is based on a vertebra with the following dimensions :

		M.
Length of centrum.....		0.031
Diameter of centrum {	vertical.....	0.039
	transverse.....	0.033

In the May number of 1878 of the *American Naturalist*, published April 22, Cope⁴ made some remarks about the homology of the chevron bones. He says: "The basal portions of the chevron bones are continued throughout the greater part of the vertebral column in the Permian genera *Clepsydrops*, *Metarmosaurus* and *Epicordylus* [*Eryops*], forming intervertebral elements to which I have given the name *intercentra*"—"The free elements of the cervical series of some reptiles are probably the same." Here the name *intercentrum* is introduced. In the same number of the *Naturalist* Cope⁵ refers to *Clepsydrops*: "*Clepsydrops* has been found to have the canine and incisor teeth distinctly characterized. The ischia are immensely enlarged in an antero-posterior direction, forming a boat-shaped body.* The neural spines of the lumbar and sacral regions are greatly elevated, indicating a fin like that of *Basiliscus*." Two new species are described, *C. natalis* and *C. gigas*, the latter of the size of the larger Mammalia.

In May, 1878, a paper by Prof. O. C. Marsh⁶ appeared in the *American Journal of Science* on Permian fossils. In the beginning he states that "hitherto no Permian vertebrates have been identified in this country, although not uncommon in Europe."

He continues: "The Museum of Yale College contains an extensive series of Reptilian remains belonging to a peculiar lacustrine fauna, which includes also Amphibians and Fishes. These fossils are from several localities in the West, but mainly from New Mexico, and the geological horizon appears to be in the upper portion of the Permian. These Reptilian remains are in excellent preservation, and among them are several genera having the more important characters of the *Rhynchocephalia*, of which the genus *Hatteria*, of New Zealand, is the living type. The principal points of agreement are the separate premaxillaries, the immovable quadrate, and the biconcave vertebræ. Another character of much interest is the presence of certain hypaxial elements of the vertebræ, first observed by Von Meyer in the Triassic genus *Sphenosaurus*, and called by him intercentral bones ('*Zwischenwirbelbein*'). These wedge-shaped bones are apparently the homologues of the cervical hypapophyses in the *Mosasauria*, and of the subcaudal attachments in the *Odontornithes*, and a few recent birds. These intercentral ossifications apparently exist in all the Reptilia yet found in this new fauna, and hence serve to distinguish it. With this character is another of hardly less interest. The anterior rib-bearing vertebræ preserved have three separate articular facets for the ribs, one on the

* This pelvis probably belongs to *Eryops*.

anterior part of the centrum for the head, and a double one above for the bifid tubercle. In the implantation of the teeth and their successional development these Reptiles resemble the Mosasauria. These characters, with others mentioned below, indicate two distinct families, which may be called *Nothodontidæ* and *Sphenacodontidæ*, from the typical genera here described.

“*Nothodon lentus*, gen. et sp. nov.

“This genus of Reptiles may readily be distinguished by the dentition. In each separate premaxillary there are two slender pointed teeth. In front of the maxillary there are one or two similar teeth, followed by a number with narrow transverse crowns, resembling in form the premolars of some carnivorous mammals. These crowns, when unworn, have a central cusp, and on each side a tubercle, somewhat like that on the premolars of the genus *Canis*. In the present species the first and last of the transverse teeth are smaller than the middle ones. The limbs were short, the long bones had their extremities covered with cartilage, but the carpals and tarsals were well ossified. The centra were very deeply concave, and the tail was long.

“The following measurements are taken from the type specimen of this species :

	MM.
Length of maxillary bone.....	65·
Space occupied by ten maxillary teeth.....	55·
Height of crown of second maxillary tooth.....	14·
Height of crown of third maxillary tooth.....	9·
Antero-posterior diameter.....	3·
Transverse diameter.....	8·
Antero-posterior diameter of eighth tooth.....	5·
Transverse diameter.....	15·

“The present species was about five or six feet in length, and herbivorous in habit. It was apparently slow in movement, and probably more or less aquatic. The remains at present known are from New Mexico.”

This is one of Cope's *Diadectidæ*.

“*Sphenacodon ferox*, gen. et sp. nov.

“In the present genus the anterior teeth are somewhat like those of the reptile described above, but the posterior, or more characteristic ones, are totally different. The crowns are much compressed, and have very sharp cutting edges, without crenulations. In the present species the carnivorous teeth are crowded together, and the crowns placed slightly oblique, and twisted. The jaws were comparatively short and massive. The

rami of the lower jaws were apparently united by cartilage only, and the symphysis was short. The vertebræ are deeply biconcave.

“Measurements from the type of this species are as follows :

	MM.
Length of dentary bone.....	150.
Space occupied by teeth.....	130.
Extent of four anterior caniniform teeth.....	25.
Extent of twenty compressed teeth.....	105.
Height above jaw of second lower tooth.....	15.
Depth of dentary bone at symphysis.....	26.
Height of crown of compressed tooth.....	8.
Transverse diameter.....	4.

“This reptile was about six feet in length, and carnivorous in habit. Its remains are from the same locality in New Mexico that yielded those of *Nothodon*.”

This is probably one of the *Clepsydropidæ*.

“*Ophiacodon mirus*, gen. et. sp. nov.

“A third genus of Reptiles allied to the last described is indicated by various well-preserved remains from the same locality. The teeth are all carnivorous in type, conical in form, and all are similar. Those in the anterior part of the jaws are recurved, and in general shape resemble those of Serpents. The rami of the lower jaws were united only by cartilage. The vertebræ are very deeply biconcave, and even perforate, and the intra-central bones large. In the present species the teeth are nearly smooth, and somewhat compressed.

“The following measurements indicate the size of this reptile :

	MM.
Extent of anterior sixteen teeth in dentary	75.
Extent of anterior five lower teeth.....	20.
Height of crown of fourth lower tooth	10.
Depth of lower jaw at symphysis	15.
Extent of seven anterior maxillary teeth.....	33.
Height of crown of first maxillary tooth.....	9.
Antero-posterior diameter of crown	3.

“This species was about as large as those described above, and is from the same geological horizon in New Mexico.

“*Ophiacodon grandis*, sp. nov.

“A second larger species of apparently the same genus is represented by portions of the jaws, and teeth, and various parts of the skeleton. In this species the dentary bone is angular at its anterior extremity, and triangular in section. Its external surface is

rugose, as in the Crocodiles. The crowns of the teeth are striate at the base, and the latter is furrowed vertically. The teeth are not so thickly set as in the smaller species, and the bases of the crowns are somewhat transverse.

“ *Measurements.* ”

	MM.
Space occupied by ten anterior lower teeth.....	140
Depth of lower jaw at symphysis.....	129
Antero-posterior extent of symphysis.....	25
Depth of dentary bone below seventh tooth.....	30
Width of dentary at this point.....	20

“ The present species was about ten feet in length, and the largest reptile yet found in this fauna. The remains are from New Mexico.”

The *Ophiacodon mirus* is one of the Clepsydripidæ, and *O. grandis* might be *Eryops* Cope.

The families “ *Nothodontidæ* ” and “ *Sphenacodontidæ* ” are, like the genera, established without diagnosis.

To this paper Cope⁷ replied in *The American Naturalist*, June, 1878. He says that the four species of reptiles are characterized by Marsh in a very insufficient manner. He should not regard his article as suitable for notice in *The Naturalist* but for certain assertions which it contains, and some circumstances connected with its publication. The assertion that “ hitherto no Permian vertebrates have been identified in this country, although not uncommon in Europe,” he declares the reverse of the fact, referring to his paper in the *Proceedings of the Academy of Natural Sciences of Philadelphia* for 1875, pp. 393–424, where some of the leading characters of the reptiles are pointed out; to his papers in the *Proceedings of the American Philosophical Society* for May, 1877, pp. 52–63, where several new species are described, and in the same journal for November, 1877, in which other species are added, making the whole number up to twenty-one. He then continues: “ These papers Prof. Marsh has had the opportunity of seeing. Two further notices of the vertebrates of the American Permian appeared on April 22, of the present year (1878), in the May number of this journal, pp. 319 and 327. As the corresponding number of the *Am. Journ. Sci. and Arts* was not issued before May 5 (perhaps a day or two sooner), Prof. Marsh had the opportunity of seeing these also. They include references to seven new genera, for most of which the characters are clearly pointed out.

“ The features common to the genera of the Permian, described by Marsh, are stated by him to be those characteristic of the order *Rhynchocephalia*; as I have already shown to be the case with the forms described by me in the earliest as well as later papers of those

cited. Another characteristic is said to be the presence of the intercentrum, a statement agreeing with my own in the May number of this journal.

"As the author of the paper does not think it necessary to allude to published sources of information, it is too much to expect him to give credit for ideas communicated to him verbally. All of the above mentioned and additional characters cited by Marsh in his two opening paragraphs as belonging to the Permian Reptiles, with others, were explained by me before the National Academy of Sciences, with Prof. Marsh as an attentive listener, at its last meeting in Washington, April 18, more than two weeks before the appearance of the paper here criticised. The characters to which I refer are 'the separate premaxillaries, the immovable quadrate and the biconcave vertebræ;' the 'hypaxial elements of the vertebræ, called [by von Meyer] intercentral bones.' 'These intercentral ossifications apparently exist in all the Reptilia yet found in this new fauna.' Compare these statements with those found in my paper read before the National Academy (which had been previously read before the American Philosophical Society, April 5) and published May 8, and that Prof. Marsh profited by what he heard is evidenced by his use of the term 'intercentra,' first introduced by myself. From this point of view it is easy to understand his attempt to make it appear that Meyer first used the word. He says, 'Another character of much interest is the presence of certain hypaxial elements of the vertebræ, first observed by von Meyer in the Triassic genus *Sphenosaurus*, and called by him intercentral bones (Zwischenwirbelbein)' (*sic*). 'As *Zwischenwirbelbein* does not mean intercentrum, but *intervertebral bone*, Prof. Marsh's knowledge of the former term must be ascribed to some other source. The fact that the *Amer. Journ. Sci. and Arts* appeared a good deal later than its usual date of publication may be considered in this connection."

On May 8, 1878,⁸ appeared the first more extensive paper of Cope on the forms from the Permian of Texas. The following new genera and species were described: *Diadectes sideropelicus* and *D. latibuccatus*; *Bolosaurus striatus* and *B. rapidens*; *Pariotichus brachyops*; *Ectocynodon ordinatus*; *Dimetrodon incisivus*; *D. rectiformis* and *D. gigas*; *Epicordylus erythroliticus*; *Metarmosaurus fossatus*; *Empedocles alatus*; *Embolophorus fritillus*; *Theropleura retroversa*, *T. uniformis* and *T. triangulata*. A new species of *Clepsydropus*, represented by numerous portions of the skeleton, was established—*C. natalis*. The skull is described: "There is no quadratojugal arch, but the zygomatic and post-orbital arches are present. The squamosal extremity of the zygomatic arch descends low on the quadrate as in turtles, preventing mobility of the latter." "The symphysis of the mandible is short, and the premaxillary bones appear to be distinct. The teeth were of different sizes and the premaxillaries and canines are distinguished from the others by their proportions. All are subround in section, with more or less defined anterior and posterior cutting edges. The premaxillary teeth are larger anteriorly, diminish pos-

teriorly, and are separated by a notched diastema from the large canine. The succeeding teeth are of medium proportion. There is no surface sculpture of the cranial bones." The vertebræ and intercentra, the greatly elevated neural spines in the lumbar and sacral regions are described, the humerus with the entepicondylar foramen and the ectepicondylar groove. The ilium, ischium and femur. In regard to the relationship of *Clepsydrops*, Cope makes the following remarks: "Of the general affinities of this genus it is only necessary now to state, that my reference of it to the *Rhynchocephalia* is confirmed. It differs from the recent species of the order in the absence of quadratojugal arch and the remarkably developed ischia. On this account I refer to *Clepsydrops* and its allies as a distinct suborder under the name of PELYCOSAURIA."

The new genus *Dimetrodon* is larger than *Clepsydrops*. The dentition is similar to that genus. The roots of the teeth are long and are contained in deep alveoli. Between the premaxillary and maxillary is a deep emargination of the border of the jaws. There are but two incisor teeth, of which the anterior is much larger than the second. The anterior two teeth of the maxillary bone are larger than the following ones, the anterior exceeding even the first incisor. The other maxillary teeth are smaller and subequal. The orbit is lateral, and has a prominent and convex superciliary border. The zygomatic arch is so curved upwards as to complete the orbit behind by the intervention of a postorbital or postfrontal bone, which separates the malar [jugal] and squamosal bones from mutual contact. In front of this bone a portion of the frontal forms the superciliary border, and in front of this, the prefrontal sends a wide process behind the lachrymal to the orbit. This bone resembles a nasal bone in form, and extends forward, and is decurved at the extremity. The width of the descending or malar process of the postfrontal is such as to partially separate the orbit from the zygomatic fossa. The superciliary surface is swollen, and is interrupted by a transverse groove on the orbital part of the prefrontal. There is a vertical open groove on the malar process of the postfrontal. Some pelvic bones are referred here. They include both the ilia, ischia and pubes in one mass, forming a compressed boat-shaped body, with a prominent inferior keel. They probably belong to *Eryops*.

Dimetrodon is said to be allied to *Deuterosaurus* Eichw. and *Eurosaurus* Fisch., as defined by Meyer. "*Deuterosaurus* has much more elevated nostrils, more numerous incisor teeth, and wants the extensive diastema in front of the superior canine. *Lycosaurus* Owen, from the South African Trias, resembles it much more nearly, but does not present the greatly enlarged anterior incisor teeth of *Dimetrodon*."

The new genera and species, *Epicordylus erythroliticus* Cope and *Metarmosaurus fossatus* Cope, which are based on vertebræ, are considered closely related to *Dimetrodon*. The new genera, *Embolophorus*, with one species, *E. fritillus*, and *Theropleura*, with

three species, *T. retroversa*, *T. uniformis* and *T. triangulata*, all based on vertebræ, are also placed near that genus.

A peculiar genus, *Empedocles* [*Empedias*] *alatus* Cope, with additional hyposphene and hypanthrum articulations, is also described.

In addition to the type of humerus referred to *Clepsydropis*, Cope describes three other humeri, which represent three other genera which have been probably already named from crania or vertebræ. Nos. 1 and 2 are compared with that of *Eurosauros*, but the epicondyles are more largely developed. No. 3 is considered as belonging to *Empedocles* [*Empedias*].

Prof. Cope concludes his paper with the following remarks: "The division *Pelycosauria* is established primarily on the genera *Clepsydropis* and *Dimetrodon*, but their cranial structures render it highly probable that *Ectocynodon*, *Pariotichus* and *Bolosaurus* belong to it. It is also probable that the genera, *Empedocles* [*Empedias*], *Embolophorus* and others determined from vertebræ belong to it, as the latter are frequently accompanied by pelvic bones of the type of that of *Dimetrodon*. All the genera known from teeth and crania are of carnivorous habit, excepting *Bolosaurus* and *Diadectes*; they may be referred to a single family on this account, which I call the *Clepsydropsidæ*. *Bolosaurus* will form the type of another family characterized by the transverse position of the crowns of the teeth, under the name of *Bolosauridæ*. Prof. Owen has named a group of Triassic and Permian reptiles the *Theriodonta*, characterized by the mammal-like differentiation of the incisor and canine teeth. The animals thus referred by Prof. Owen probably enter my suborder of *Pelycosauria*, although the structure of their pelvis remains to be ascertained. If so, they correspond with my *Clepsydropsidæ*, since Prof. Owen does not include herbivorous forms in his division. As it is plain that the herbivorous and carnivorous types belong to the same order, and probably suborder, it becomes necessary to subordinate the term *Theriodonta* to that of *Pelycosauria*. To another division of reptiles from the South African Trias, typified by the genus *Pareiasaurus* Owen, he gives a special name, expressive of the deeply impressed surfaces of the centra occupied by the remains of the *chordæ dorsalis*. As this, or the perforate condition, is characteristic of all of the *Pelycosauria*, it is probable that it is present in Prof. Owen's *Theriodonta* also. It is also evident that since the dental characters of *Pareiasaurus* do not serve to distinguish it as an order from the genera with distinct canine teeth, this group also must be looked upon as a subdivision, perhaps of family value, of the *Pelycosauria* or other parts of the Rhynchocephalous order."

In regard to the geological formation of the Illinois and Texas beds, he comes to the conclusion that they are Permian.

On the 7th of November, 1878, Prof. Cope⁹ read a paper before the National Acad-

emy of Sciences, at its meeting in New York, on the *Theromorphous Reptilia*. "He stated that he had determined that the scapular arch in the *Pelycosauria* consists of scapula, coracoid and epicoracoid, which form a continuum in the adult, in the same way as the three elements of the pelvis in the same group form an os innominatum. He showed that the tibiale and centrale of the tarsus unite to form an astragalus, which has no movement on the tibia. The fibulare forms a calcaneum. The distal side of the astragalus presents two facets, one of which receives a large part of the proximal extremity of the cuboid.

"The structure of the scapular and pelvic arches was stated to be identical with that already described by Owen as belonging to the *Anomodontia*. Several important characters distinguish this group from the *Pelycosauria*, but the two together form an order, which Prof. Cope thought would have, for the present at least, to be retained as distinct from the *Rhynchocephalia*. The characters of this order, with its two suborders, were given as follows :

"*THEROMORPHA* Cope. Scapular arch consisting at least of scapula, coracoid and epicoracoid, which are closely united. Pelvic arch consisting of the usual three elements, which are united throughout, closing the obturator foramen [f. pubo-ischiaticum] and acetabulum. Limbs with the phalanges as in the ambulatory types. Quadrate bone proximally united by suture with the adjacent elements. No quadratojugal arch.

"*Pelycosauria*. Two or three sacral vertebræ ; centra notochordal ; intercentra usually present. Dentition full.

"*Anomodontia*. Four or five sacral vertebræ ; centra not notochordal ; no intercentra. Dentition very imperfect or wanting.

"The *Rhynchocephalia* have no distal ischio-pubic symphysis, and apparently no epicoracoid bone. They have an obturator foramen [foramen pubo-ischiaticum] and a quadratojugal arch.

"The order *Theromorpha* was regarded by Prof. Cope as approximating the *Mammalia* more closely than any other division of *Reptilia*, and as probably the ancestral group from which the latter were derived. This approximation is seen in the scapular arch and humerus, which nearly resemble those of the *Monotremata*, especially *Echidna* ; and in the pelvic arch, which Owen has shown in the *Anomodontia* to resemble that of the Mammals, and, as Prof. Cope pointed out, especially that of *Echidna*. The tarsus is also more mammalian than in any other division of reptiles. In the genus *Dimetrodon* the coracoid is smaller than the epicoracoid, as in Monotremes. The pubis has the foramen for the internal femoral artery."

At the end of this note a new species of *Dimetrodon* is described under the name of *D. cruciger*. "It is characterized by the enormous length of the neural spines of the

lumbar vertebræ, which form the dorsal fin seen in other species of the genus. In this species the spine sends off, a short distance above the neural canal, a pair of opposite short branches, forming a cross. At various more elevated positions there are given off tuberosities, which alternate with each other." This species of *Dimetrodon* was later made the type of *Naosaurus* Cope.

Cope's "Second Contribution to the History of the Vertebrata of the Permian Formation of Texas"¹⁰ appeared June 5, 1880. The general conclusions about the *Theromorphia* he had already published in the *American Naturalist*, December, 1878, which we have reviewed above. Cope now believes that the *Pelycosauria* are related to the *Amphibia* in some important respects (scapular and pelvic arches, humerus, dentition of palatal region), but he says: "In spite of these approximations, the *Pelycosauria* are distinctly reptilian in their single occipital condyle, ossification of the basi-cranial axis and single vomer."

"Thus the reptiles and batrachia of the Permian period resemble each other and the *Mammalia* more closely than do the corresponding existing forms."

The genus *Theropleura* is more fully defined from a better preserved specimen of *Theropleura uniformis* than any so far obtained. "The teeth are generally similar to those of *Clepsydrops* and *Dimetrodon*, having compressed crowns with fore and aft cutting edges. The incisors are distinguished by the presence of a diastema. Posteriorly to this the teeth increase in size and then diminish; one tooth near the middle of the series is the largest, but does not in this species very much exceed the others. There is at least one large incisor tooth. The bones of the head are smooth and not sculptured. The symphysis of the mandible is short." The neural arches are distinct from the centra. Intercentra are said to be absent in the thirteen vertebræ preserved; but there was probably one below the centrum of the atlas. The ribs are two-headed, the capitular process extending downwards to the anterior border of the centrum. The neural spines of some of the vertebræ are greatly elevated, as in the species of *Clepsydrops* and *Dimetrodon*. Dermal rods are said to be present, suspected to be abdominal, and this is considered a batrachian character. The neural spine of the axis is extended fore and aft. The odontoid is distinct and is of large size. It has lateral and inferior articular surfaces.

Theropleura uniformis is described to be of the size of the larger *Varanidæ*, and about equal to the *Clepsydrops natalis*. It is characterized by a long and acuminate head, with a large lateral nostril on each side, well forwards and approaching near the border of the diastema. Anterior to the large lateral tooth there are nine teeth; posterior to it there are eighteen. Length of alveolar edge of mandible 0.120 m.

A new species of *Theropleura* is described as *T. obtusidens*, represented by nearly

all parts of the skeleton, including jaws of both sides with teeth, numerous vertebræ and bones of the limbs.

The neural arches are coössified with the centrum. The jaws are long and slender and the teeth are of equal size. The number of teeth in the dentary is about twenty-one. The mandibular articular face consists of two open parallel grooves, one shorter than the other, extending obliquely to the long axis of the jaw. A dentigerous bone of the palate is described.

The vertebræ have simple elongated neural spines. Intercentra are indicated by the shape of the vertebræ, but not preserved. Traces of sutural articulation with the neural arches remain. Many of the centra are much compressed and have a narrow, sharp median keel.

Dimetrodon is more fully described; the vertebræ and a portion of the muzzle are figured. Parts of the palatopterygoid are described, probably pieces of the palate and pterygoid; both bear teeth. The posterior part of the skull displays typical reptilian characters. The occipital condyle is described as not perforated nor divided by sutures. The exoccipital bones [paroccipital processes] project well backwards. The lateral walls of the brain-case are massive as far forwards as the exit of the fifth pair of nerves; anterior to this point they were thin or wanting. The basisphenoid carries two parallel descending laminae, which bound a deep median fissure, and then unite anteriorly. Posteriorly they abut on a descending process, which is followed by a lid-like element which is applied to a circular fossa with a raised border near the occipital condyle.

The articular face of the articular bone of the mandible consists of two parallel cotyli, divided by a ridge of articular surface. [This is the quadrate.] This part of the jaw is much depressed, as in *Eryops*. The large teeth of the lower jaw are at the anterior extremity. The neural spine of the axis is flat and elongate antero-posteriorly. From this point the neural spines rise rapidly in elevation until on the dorsal region they are many times as long as the diameters of the centra. Intercentra are present in the dorsals; and all the ribs are two-headed, from the axis. All the cervical and dorsal vertebræ have diapophyses with tubercular facets. The head of the rib is prolonged downwards and forwards to the prominent border of the anterior articular face, against which it abuts, but so far as yet observed without a corresponding facet. [The facet is on the intercentrum.] On the caudal vertebræ the two facets of the ribs are approximated and finally are not distinguished. They are here coössified with the centra. Then follow short notes on humerus, pelvis and femur.

Three species are distinguished as follows:

- Vertebral centra much compressed, acute below; neural spines without processes.....*D. incisivus*.
- Vertebral centra less compressed, obtuse below; neural spines without processes, larger.....*D. gigas*.
- Vertebral centra compressed, not acute below; neural spines with cross projections.....*D. cruciger*.

The characters of *Dimetrodon cruciger* Cope, already given in *American Naturalist*, December, 1878, p. 830, are noted again.

A new genus *Helodectes* is established. It has the molar teeth in two series. Two species are named *H. paridens* and *H. isacii*.

In the *American Naturalist* of February, 1881, Prof. Cope¹¹ gave a list of the Vertebrates of the Permian Formation of the United States.

The following *Reptilia* are catalogued:

THEROMORPHA Cope.

Pelycosauria Cope.

<i>Diplocaulidæ.</i>	<i>Theropleura uniformis</i> Cope, Texas.
<i>Diplocaulus salamandroides</i> Cope, Eastern Illinois.	“ <i>triangulata</i> Cope, Texas.
<i>Clepsydropsidæ.</i>	“ <i>obtusidens</i> Cope, Texas.
<i>Pariotichus brachiops</i> Cope, Texas.	<i>Metarmosaurus fossatus</i> Cope, Texas.
<i>Ectocynodon ordinatus</i> Cope, Texas.	<i>Embolophorus fritillus</i> Cope, Texas.
<i>Archæobelus vellicatus</i> Cope, Eastern Illinois.	<i>Lysorophus tricarinatus</i> Cope, Eastern Illinois.
<i>Clepsydrops colletii</i> Cope, Eastern Illinois.	<i>Bolosauridæ.</i>
“ <i>vinslovi</i> Cope, Eastern Illinois.	<i>Bolosaurus striatus</i> Cope, Texas.
“ <i>pedunculatus</i> Cope, Eastern Illinois.	<i>Diadectidæ.</i>
“ <i>natalis</i> Cope, Texas.	<i>Diadectes sideropelicus</i> Cope, Texas.
<i>Dimetrodon incisivus</i> Cope, Texas.	“ <i>phaseolinus</i> Cope, Texas.
“ <i>rectiformis</i> Cope, Texas.	<i>Empedocles alatus</i> , Cope, Texas.
“ <i>biradicatus</i> Cope, Texas.	“ <i>latibuccatus</i> Cope, Texas.
“ <i>gigas</i> Cope, Texas.	“ <i>molaris</i> Cope, Texas.
“ <i>cruciger</i> Cope, Texas.	<i>Helodectes paridens</i> Cope, Texas.
<i>Theropleura retroversa</i> Cope, Texas.	“ <i>isacii</i> Cope, Texas.

The next paper of Cope¹² is “On Some New Bratrachia and Reptilia from the Permian Beds of Texas.” A new species of *Dimetrodon* is described under the name of *D. semiradicatus*; based on premaxillary and maxillary bones. There are three teeth on each premaxillary; in the maxillary 17 or 18. The first premaxillary and third maxillary are of nearly equal size and are much larger than the others, the second premaxillary only approaching them. Besides, the clavicles of *Dimetrodon cruciger* are discussed and compared with the corresponding elements of the *Stegocephali*.

In November, 1884, Prof. Cope¹³ published his fifth contribution to the knowledge of the Permian Vertebrates. A new species of *Clepsydrops*, *C. leptcephalus*, is described. “This species is represented by almost the entire skeleton, the principal deficiency being that of the scapular arch and the anterior limbs, with the phalanges of the posterior feet.”

The bones of the skull are mostly preserved. The *quadrate* bones are rather short, and articulate above by squamosal suture with the squamosals, which overlap them pos-

teriorly. They narrow upwards, and are deeply grooved on the anterior face below. Each edge of the groove is produced forwards; the external for a considerable distance as an acuminate laminiform process, in the usual position of a quadratojugal bone. The *pterygoids* were probably placed much as in *Empedias molaris* Cope (*Proc. Am. Philos. Soc.*, Vol. xix, p. 56, Pl. V). They send inwards a subtriangular plate from each side, which approach each other on the median line without touching, and the adjacent edges are somewhat decurved. The posterior edges are deeply concave on each side of the middle line, and, like the inferior edges, are dentigerous. The process for the quadrate extends outwards and backwards, and is thickened on its posterior edge, while its anterior edge, which is continued from the inferior edge of the posterior border, becomes very thin. The anterior production for the ectopterygoids extends outwards and forwards, leaving the anterior edge of the dentigerous plates as the concave posterior border of the large palatine foramina. The anterior production of the internal edge of the plate becomes very thin, and is broken in the specimen without showing articulation for the palatine.

The *squamosal* extends both above and below its anteriorly directed zygomatic portion. The superior extremity shows squamosal suture for the parietal. The *stapes* (Pl. I, Fig. 2, a, b, c, d) is of large size. It consists of a stout rod terminating in a double extremity, something like the double head of a rib. The shorter head is expanded into a funnel shape. Near to it the shaft is perforated in the longer diameter by a foramen. The extremity of the other head is transversely truncate, and is separated from the funnel by a deep notch. On the outer side of the fundus of this notch a foramen penetrates the shaft obliquely, and is continued into a canal which issues at the foramen first described. The distal end is truncated by an irregular sutural surface. The premaxillaries are distinct. The teeth of that bone and of the maxillary are of unequal size.

The axis has an expanded neural spine and a diapophysis for rib articulation, but no parapophysis or capitular fossa. Behind the axis follow twenty-six vertebræ in a continuous series. All bear diapophyses, and all are rib-bearing, except perhaps the last two, where they are of reduced size. They are more or less opposite the neural canal as far as the twenty-second centrum. On this centrum the superior edge is on a level with the floor of the canal, and posterior to this point the diapophyses rise from the centrum. Two sacrals and ten caudals are preserved. The intercentra are short and not extended upwards on the sides. The neural spines were probably not elongated, as in *Dimetrodon*, though they are unfortunately broken off.

A new species of *Clepsydropus*, *C. macrospondylus*, is described, much exceeding *C. natalis* in dimensions. The dentary bone supports one or two large teeth near the extremity. There are preserved the axis, twelve continuous dorsals, nine other continuous vertebræ, of which three are lumbar, two sacral, and four caudal. Intercentra are

present. The centra are strongly compressed, and on the anterior part of the column have an obtuse hypophysial keel. The intercentra display equal width on the inferior surface, and are abruptly rounded at the extremities. The last one preserved is between the second and third caudal centra. The sacrum is rather robust. The sacral vertebræ are free, have well-developed neural spines and large free ribs for the ilium.

A new species of *Edaphosaurus*, *E. microdus*, is described. The genus *Edaphosaurus* was established on *E. pogonias*, represented by a specimen, which included only a distorted cranium. The new species is based on numerous vertebræ and ribs and the dentigerous plates of both jaws. The vertebræ possess enormously elongated neural spines as in *Dimetrodon*. The centra have a facet on the anterior edge above the middle for the head of the rib, as in a mammal. It is not repeated on the posterior edge of any of the thirteen centra preserved. The ribs are only compressed proximally. Distally their section is a wide oval.

The centra are rather elongate, and the *foramen chordæ dorsalis* is rather large. No intercentra are preserved, and if present they must have been very small, as the inferior rim of the centrum is not beveled to receive one. The neural spines have transverse processes which commence near the base, and project at intervals from the sides.

A special portion of the paper treats the *posterior foot* in the *Pelycosauria* (*Clepsydraps natalis*, Pl. I, Figs. 5, 6).

The astragalus and calcaneum are large and well-specialized bones free from each other and the other tarsal elements. The navicular is distinct. There are four tarsals in the distal series. Three are articulated with the metatarsals 1 to 3, the fourth with metatarsal 4 and 5. These elements are tarsal 1 (entocuneiform), tarsal 2 (mesocuneiform), tarsal 3 (ectocuneiform), and tarsal 4 and 5 (cuboid). There is a face on the astragalus for another element, which Cope thinks might have been a spur, as in the Monotremata.

The following conclusions are reached :

"1. The relations and number of the bones of the posterior foot are those of the Mammalia much more than those of the Reptilia. 2. The relations of the astragalus and calcaneum to each other are as in the Monotreme *Platypus anatinas*. 3. The articulation of the fibula with both calcaneum and astragalus is as in the Monotreme order of mammals. 4. The separate articulation of the anterior part of the astragalus with the tibia is as in the same order. 5. The presence of a facet for the articulation of a spur is as in the same order. 6. The posterior-exterior direction of the digits is as in the known species of Monotremata."

"Thus the characters of the posterior foot of the *Pelycosauria* confirm the evidences of Monotreme affinity observed by Prof. Owen and myself in the bones of the legs,

especially of the anterior leg. It remains a fact that with this resemblance in the leg there is a general adherence to the reptilian type in the structure of the skull." But this adherence is not so exclusive as has been supposed, as he endeavors to show.

An account is now given of the structure of the *columella auris* in *Clepsydropus leptcephalus*. The columella resembles a rib, of which the suprastapedial process resembles the head, and the stapes the tubercle. If this process be the incus, the stapes is shortened as in the majority of *Mammalia*. We have here an approximation to the *Mammalia* in two points: (1) The perforation of the head of the stapes; (2) and the ossification of the incus, which (3) is distinct from the malleus, thus furnishing homologues of the principal ossicles of the ear.¹⁴

The structure of the quadrate bone in the genus *Clepsydropus* is then discussed. This bone in *Clepsydropus leptcephalus* Cope, already described, is of highly interesting form. Its lower horizontal process is homologized with the zygomatic process of the squamosal bone of the *Mammalia*, forming with the malar bone the zygomatic arch. "*In the Pelycosauria there is but one posterior lateral arch*, as is demonstrated by many specimens; hence, we have here a reptile with a zygomatic arch attached to the distal extremity of the quadrate bone."

After this some remarks follow about *the articulation of the ribs in Embolophorus*. "The ribs of the *Theromorpha* are two-headed. While the tubercular articulation has the usual position at the extremity of the diapophysis, the capitular is not distinctly, or is but partially indicated, on the anterior edge of the centrum, in *Clepsydropus* and *Dimetrodon*. In *Embolophorus*, as shown in 1878, the capitular articulation is distinctly to the intercentrum." Therefore the ribs of the *Theromorpha* are intercentral and not central elements, and are homologues, according to Cope, of the chevron bones [!]. This type of rib articulation also *approximates closely that of the Mammalia*, where the capitular articulation is in a fossa excavated from two adjacent vertebræ.

Finally *the origin of the Mammalia* is discussed. *The Mammals are considered as the descendants of the Pelycosauria*, and a table shows the relations between the *Amphibia*, *Pelycosauria*, other *Reptilia*, and the *Mammalia*. The same results were published in the *Proc. Amer. Assoc. Adv. Science*,¹⁵ Vol. xxxiii, pp. 471-482, 1 Pl., Salem, 1885, with the title, "The Relationships Between the Theromorphous Reptiles and the Monotreme Mammalia." In April, 1885, Prof. Cope¹⁶ published a paper "On the Evolution of the Vertebrata, Progressive and Retrogressive." Here he derives all *Reptilia*, with the possible exception of the *Ichthyosauria*, from the *Theromorpha*.

In April, 1886, Cope¹⁷ gave figures of the vertebræ of *Clepsydropus natalis* Cope. In June of the same year he established the genus *Naosaurus*, in a paper with the title,

“The Long-spined Theromorpha of the Permian Epoch.”¹⁸ Referring to *Dimetrodon* he says :

“The huge neural spines formed an elevated fin on the back. In a medium-sized specimen of *Dimetrodon incisivus*, where the vertebral body is 35 mm. in length, the elevation of the spines is 900 mm., or twenty and a half times as great. The apex of the spine in this species is slender, and apparently was flexible. The utility is difficult to imagine. Unless the animal had aquatic habits, and swam on its back, the crest or fin must have been in the way of active movements. Accordingly the spines are occasionally found distorted at the union of the faces of fractures. The limbs are not long enough nor the claws acute enough to demonstrate arboreal habits, as in the existing genus *Basiliscus*, where a similar crest exists. A very peculiar species has been described under the name of *Naosaurus claviger* Cope. There the spines are not quite so elevated as in the *D. incisivus*, but they are more robust, and have transverse processes or branches which resemble the yardarms of a ship mast. In a full-sized individual the longest cross-arms, which are the lowest in position, have an expanse of 260 mm., or ten and a quarter inches, while the spine has about the height of 500 mm. (19.75 in.), the body being 60 mm. long. The animal must have presented an extraordinary appearance. Perhaps its dorsal armature resembled the branches of shrubs then, as they do now, and served to conceal them in a brushy or wooded region ; or, more probably, the yardarms were connected by membrane with the neural spine or mast, thus serving the animal as a sail with which he navigated the waters of the Permian lakes. A very singular character of the spines in all the species is that they are hollow, as in *Cœlacanth* fishes, and that the central cavity is not closed at the apex.

“There is a well-preserved cranium of the *D. claviger*, but the muzzle is unfortunately wanting. The median line rises forward so that the convexity of the top of the muzzle is higher than the posterior parts of the skull, whose profile descends rapidly. This throws the orbit far back, and gives the animal a peculiar appearance. *Naosaurus* differs from *Dimetrodon* in the transverse processes of the neural spines of the vertebræ. There are three species, which differ as follows :

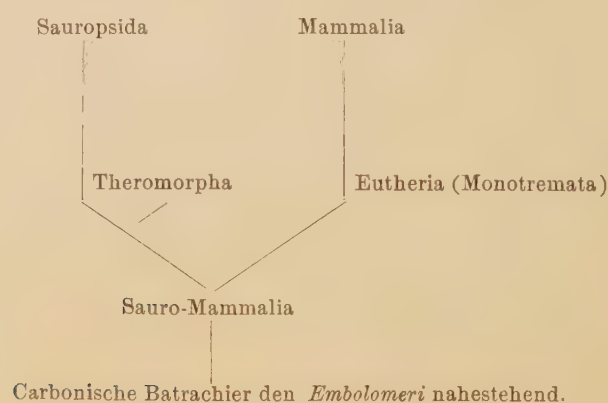
Spines of vertebræ cylindrical distally ; transverse processes replaced above by tuberosities	<i>N. cruciger</i> .
Spines of vertebræ expanded and compressed above. Palatine teeth large, forming a pavement.....	<i>N. microdus</i> (<i>Edaphosaurus microdus</i> Cope).
Palatine teeth much smaller and more widely spaced.....	<i>N. claviger</i> .

“All these species are from the Permian formation of Texas.”

In a paper by Baur¹⁹ on the humerus of the Amniota, published in 1886, a few remarks are made on the relationship of the Theromorpha and the Mammalia. Baur

says: "Cope betrachtet die Pelycosauria als die Ahnen der Säugethiere. Ich glaube jedoch, dass dieselben schon etwas zu stark specialisirt sind, um diesen Anforderungen entsprechen zu können.

"Darüber aber kann kein Zweifel sein, dass die Pelycosauria den Stammaltern der Säugethiere sehr nahe stehen. Beide sind vielleicht aus derselben Gruppe hervorgegangen, einer Gruppe, welche zwischen den Batrachiern und Reptilien des Perm in der Mitte stehen würde, und welche ich Sauro-Mammalia nennen möchte. Folgendes Schema möge den Zusammenhang ausdrücken:



A new catalogue of Permian vertebrates was published by Cope²⁰ in October, 1886.

Theromorpha.

Clepsydropidæ.

? *Lysorophus* Cope, 1877.

L. tricarinatus Cope, 1877, Eastern Illinois.

Archæobelus Cope, 1877.

A. vellicatus Cope, 1877, Eastern Illinois.

Clepsydrops Cope, 1875.

C. collettii Cope, 1875, Eastern Illinois.

C. vinslovii Cope, 1877, Eastern Illinois.

C. pedunculatus Cope, 1877, Eastern Illinois.

C. natalis Cope, 1878, Texas.

C. macropondylus Cope, 1884, Texas.

C. leptcephalus Cope, 1884, Texas.

[*C. limbatus* Cope, 1877, Texas, not mentioned]

Dimetrodon Cope, 1878.

D. gigas Cope, 1878, Texas.

D. incisivus Cope, 1878, Texas.

D. rectiformis Cope, 1878, Texas.

D. semiradicatus Cope, 1878, Texas.

Naosaurus Cope, 1886.

N. cruciger Cope, 1878 (*Dimetrodon*), Texas.

N. claviger Cope, 1886, Texas.

N. microdus Cope, 1884 (*Edaphosaurus*), Texas.

Theropleura Cope, 1878.

T. retroversa Cope, 1878, Texas.

T. uniformis Cope, 1878, Texas.

T. triangulata Cope, 1878, Texas.

T. obtusidens Cope, 1880, Texas.

Embolophorus Cope, 1878.

E. fritillus Cope, 1878, Texas.

E. dollovianus n. sp. Cope, 1886.

Edaphosaurus Cope, 1882.

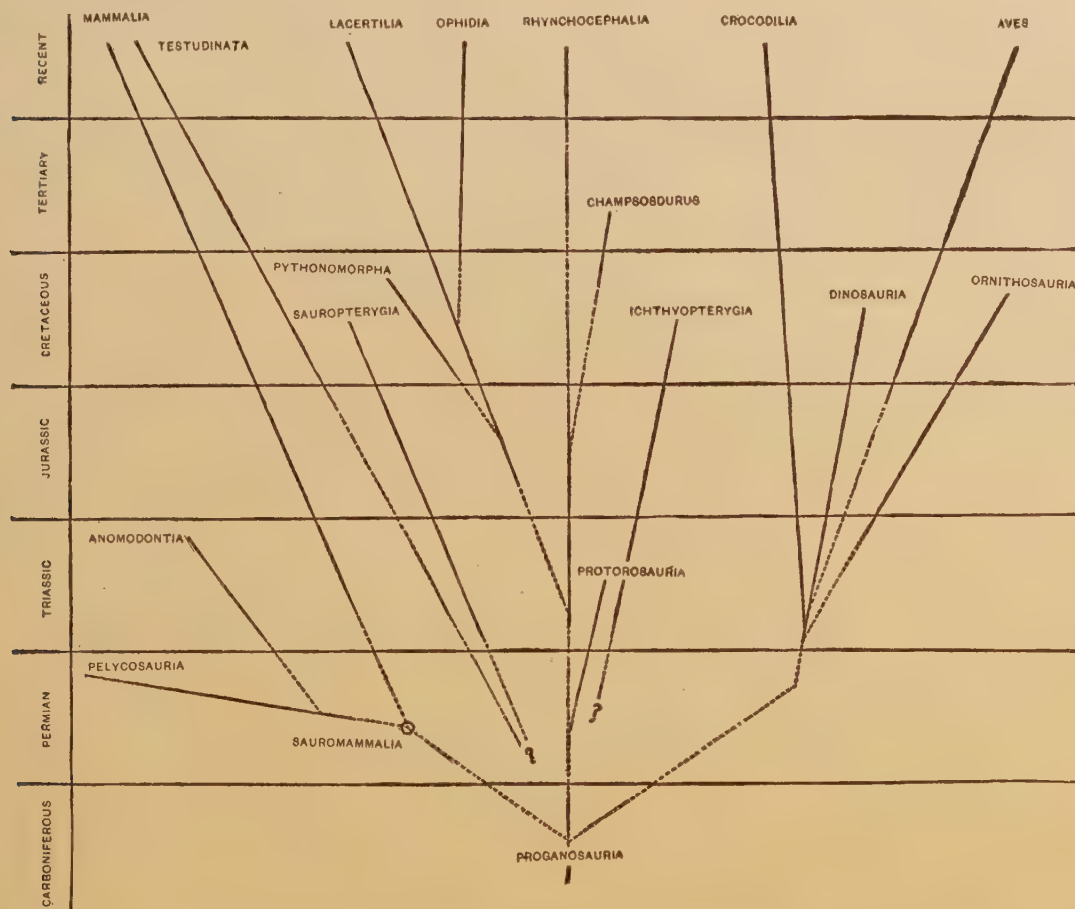
E. pogonias Cope, 1882.

Remarks are made about *Dimetrodon* and *Naosaurus*.

"In a medium-sized specimen of *Dimetrodon incisivus*, where the vertebral body is 35 mm. in length, the elevation of the neural spine is 900 mm., or twenty and a half times as great." The interclavicle is described as *sternum* and figured Pl. III, Fig. 5. A posterior foot of *Theropleura* (spec. ?) is figured and described.

Naosaurus differs from *Dimetrodon* in the presence of transverse processes on the neural spines. Portions of the skull and vertebræ of *Naosaurus claviger* are described and figured (Pl. II, Figs. 1-3; Pl. III, Fig. 1). Vertebræ of *Naosaurus cruciger* and *N. microdus* are also figured (Pl. III, Figs. 2 and 3).

In 1887 Baur^{21, 22, 23} gave the following diagram to express the relationship between the *Theromorpha*, the other Reptiles and the Mammals:



Lydekker in 1890²⁴ describes some Pelycosaurian remains from the Permian of Texas in his "Catalogue of the Fossil Reptilia and Amphibia in the British Museum," Part IV. 1. Pieces of the maxilla and neural spines of *Naosaurus cruciger* Cope. 2. Portions of spines of *Naosaurus claviger* Cope, and of undetermined species of *Naosaurus*. 3. Two dorsal vertebræ and an intervening intercentrum of *Embolophorus* spec. 4. Two dorsal

vertebræ and an intercentrum, and two other portions of dorsal vertebræ of *Embolorphorus dolloverianus* Cope.

The next paper to be mentioned is by Prof. Cope,²⁵ "On the Homology of the Posterior Cranial Arches in the Reptilia," published in April, 1892.

Clepsydropus leptcephalus Cope is made the type of a new genus, *Diopseus* Cope. The following species have well-preserved crania which display sutures: *Chilonyx rapidens* Cope; *Pantylus cordatus* Cope; *Pariotichus megalops* Cope; *Edaphosaurus pogonius* Cope; *Clepsydropus natalis* Cope; *Naosaurus claviger* Cope; *Diopseus leptcephalus* Cope.

"The genera *Chilonyx*, *Pantylus* and *Pariotichus* have the temporal fossæ entirely roofed over, thus belonging to the *Cotylosauria*, to which must be probably referred the genus *Pareiasaurus* Owen, of the South African Karoo formation, and the *Phanerosaurus* of the German Permian. The other genera, excepting *Diopseus*, belong to the *Pelycosauria*, which is probably the same as the *Theriodontia* of Owen.

"*Chilonyx* agrees with the *Stegocephalia* and with other *Diadectidæ* in possessing a distinct *os intercalare* [*epiotic* aut.; *paroccipital plate*, Baur,²⁶ 1889; *os tabulare* or *tabular bone*, Cope,²⁷ 1894]. The component elements of the cranial roof are equal in number and similar in position to those of the *Stegocephalian* skull, except that the supramastoid [squamosal] extends between the parietal and intercalare [paroccipital plate] to the posterior border of the cranial table (Fig. 2, Sm.); and the supraoccipital does not extend on to the superior face of the skull, except as a narrow border. The quadrate bone is directed forwards instead of posteriorly, which causes an antero-posterior abbreviation of the supratemporal [prosquamosal] and squamosal elements. The elements of the temporal roof are not exclusively tegumentary, but are identical in character with the bones of the brain case, and the sutures are visible on the under as well as the upper side.

"*Pantylus* agrees with *Chilonyx* in the composition of its cranial roof with the exception that the suspensorium is vertical and is not directed forwards" (Fig. 4, Pl. I).

"*Pariotichus* Cope agrees in the main with *Chilonyx*, but the supraoccipital is divided medially and is reflected on to the superior face of the skull as in *Stegocephali*. The intercalare [paroccipital plate] is reduced to a small element, of which a small part appears on the superior face of the skull immediately behind the exterior part of the supramastoid" [squamosal] (Fig. 3, Pl. I).

Then it passes to the *Theriodontia* (*Pelycosauria*).

In "*Naosaurus* Cope (Fig. 7, Pl. II), the orbit is in the posterior part of the skull and the muzzle is greatly elevated and compressed [?]. The zygomatic (quadratojugal) is greatly decurved posteriorly and the supratemporal [prosquamosal] is accordingly decurved also. The postfrontal (Fig. 7a) is a narrow bone, wider than long, and it has connection with the frontal, parietal and postorbital only. The postorbital is an L-shaped

structure, of which the shorter limb is inferior, extending to the jugal, while the longer limb is posterior, extending to the supratemporal [prosquamosal], in contact with the parietal. It encloses no foramen with the latter; but it encloses a larger foramen with the jugal, zygomatic [quadratojugal] and supratemporal [prosquamosal] at the other boundaries. This is the infratemporal foramen of Baur. Posterior to the parietal is a small transverse element, which appears to be merely adherent to the former. Its determination is not easy at present. The supratemporal [prosquamosal] is elongate vertically, and narrow antero-posteriorly. Beneath and towards the middle line of the skull is a part of another bone which may be the paroccipital, or even exoccipital. The pineal foramen is distinct. No parietoquadrate arch."

"In *Clepsydrops* the structure is apparently the same, although the form is much less modified. The quadrate articulation is nearly in line with the maxillary dental series (Fig. 6, Pl. II), and the jugal is nearly horizontal; its inferior border being concave upwards. No bar extends posteriorly from the postorbital, which joins the supratemporal [prosquamosal], enclosing with it the infratemporal foramen. No indication of a supratemporal foramen can be found in the rather mutilated specimen. I think it was not present."

"In *Edaphosaurus* Cope (Fig. 5, Pl. II), the skull is of a more depressed type than in the preceding genera. The postorbital is mainly preserved, and it is in contact with the frontal proximally, and sends out no bar posteriorly. There was apparently no supratemporal foramen, but a very large infratemporal, which extended well upwards. There is no parietoquadrate arch. An element, perhaps supraoccipital, terminates in a free compressed apex on each side of the median posterior region. This may be homologous with the small free bone described in *Naosaurus*, in nearly the same position. The stapes is very large, and is at least partially perforated near the expanded proximal extremity. It is probably fully perforated, as I have described it in the *Diopelus leptcephalus* Cope."

"In *Diopelus* Cope, the supratemporal is elongate in the vertical direction, and as elsewhere it overlaps the quadrate at the distal extremity. Anteriorly, it sends forwards a process probably for union with the postorbital bone, which is, however, entirely free from the parietal, and encloses a foramen with it, precisely as in *Sphenodon*. It further resembles the corresponding element in *Sphenodon* in sending upwards a branch for union with the parietal. Thus there are in this genus two posterior bars and two foramina, thus differing widely from the other Permian genera of this or any other country known to me. Whether it has a free parietoquadrate arch I do not know, but it is probable that the genus should be referred to the *Rhynchocephalia*, in the neighborhood of *Palæohatteria* Cred. It differs from *Sphenodon* and resembles closely the *Theriodontia* in the absence of an obturator foramen, and in the character of its dentition. The zygomatic

bone [quadratojugal] is not excavated below, but has a straight outline to its junction with the jugal. The quadrate condyle is double like that of *Sphenodon* and the *Clepsydropsidæ*" (Fig. Pl. II).

"The *Theriodonta* described by Owen appear to have the single cranial arch constructed in the same way as I described above as characteristic of the American forms. I gather this from Owen's figures of the genera *Kistecephalus* Ow., *Galesaurus* Ow., *Scaloposaurus* Ow., *Anthodon* Ow., and apparently *Lycosaurus* Owen."*

The posterior region of the *Anomodontia* is then discussed. They possess an "extensive supratemporal foramen, and that the bone which bounds it externally consists posteriorly of the supratemporal bone [squamosal], and not the zygomatic [quadratojugal]. Anteriorly this bone joins the postorbital, postfrontal and malar" [jugal]. "It is evident then that the *Anomodontia* differ from the *Theriodonta* in the absence of a zygomatic [quadratojugal] arch, and in the presence of a supratemporal arch, which is separated from the parietal bone by a supratemporal foramen."

Prof. Cope thus reaches the conclusion that there are four types of crania represented in the Permian Reptilia, which he distinguishes as follows :

Temporal roof uninterrupted.....	<i>Cotylosauria</i> .
A zygomatic arch, but no distinct supratemporal or supramastoid arches.....	<i>Theriodonta</i> .
Zygomatic and supratemporal arches.	<i>Diopseus</i> .
No zygomatic ; a supratemporal arch.....	<i>Anomodontia</i> .

Discussing the *parietoquadrate arch*, Prof. Cope remarks : "The parietoquadrate arch is a later appearance in geologic time. It is not present in any of the Permian orders."

In 1897, Baur and Case²⁸ showed that the *Pelycosauria* possess two temporal arches, an upper postorbital-squamosal and a lower quadratojugal arch, besides the parietoquadrate arch. They also demonstrated that the *Pelycosauria* are specialized *Rhynchocephalia*, which die out during the Permian, and cannot be the ancestors of the *Mammalia*.

Shortly before his death, Prof. Cope²⁹ wrote a review of this paper with discussions, which was published in the *American Naturalist* of April, the last number he edited.

THE PELYCOSAURIA FROM THE PERMIAN OF FRANCE.

The first remains of Permian Reptiles, which we consider as Pelycosaurian, were described in 1856 by Coquant,³⁰ and later redescribed and figured by Gervais.³¹

They consisted of an upper jaw of a Reptile, found near Moisse, which was considered by Coquant as belonging to *Protorosaurus*. It is preserved in the Museum of

**Procolophon* Ow. is also placed here.

Besançon. Gervais has examined these fossils and has given figures of them. "La pièce (Fig. 29) est longue de 0.065 m.; elle se compose d'un fragment considérable de la maxillaire gauche, portant une dent caniniforme suivie de huit autres dents plus petites et décroissantes dont la première est à quelque distance de celle qui par sa grandeur et sa forme peut être considérée comme une canine. Les dents sont comprimées, subcunéiformes, très-faiblement striées longitudinalement, à bords antérieur et postérieur subtranchants, mais non denticulés en scie. Cette de ces dents qui occupe la position antérieure est aussi la plus grande et elle est comparable à une canine, distante de la première de celles qui suivent d'une longueur de 0.010. Sa hauteur, audessus du bord du maxillaire, est de 0.020, et sa longueur, à la base, de 0.007. La plus grande des dents qui la suivent n'a que 0.010 de fût. Les dents placées après celle-là vont en décroissant. On se rend fort bien compte de la disposition des dents placées en arrière de la canine et de leur grandeur décroissante par l'inspection de la contreempreinte du même morceau (Fig. 30).

"On y voit, en avant de la canine, l'indice de quatre autres dents subégales entre elles, dont la quatrième, en comptant d'avant en arrière, est sensiblement écartée de la canine elle-même, comme l'est d'ailleurs la première des dents de l'autre série. Les dents étaient à peu près, triangulaires à leur couronne, et leur forme était assez peu différente de celle des dents placées en arrière de la canine. Les quatre empreintes de dents, celle de la canine et celles des huit dents qui suivent cette dernière, occupent ensemble, une ligne courb dont l'arc mesure 0.085."

Gervais denies the identity of this fossil with *Protorosaurus*; according to him it seems related to the *Geosaurs*, and he names it provisionally *Geosaurus* (?) *cynodus*.

It is evident that it is no crocodile; it can only be compared with the Pelycosauria. It seems to be different from *Stereorachis* Gaudry.

Stereorachis dominans Gaudry, 1880.

The genus *Stereorachis*, from the Permian of Autun, was first described by Gaudry³² in 1880. A more complete account with figures appeared in 1883.³³

Of *Stereorachis* the following remains are preserved: The lower jaw about 135 mm. long is in very poor condition; thirteen teeth are present, the most anterior one is the largest. The maxillary is partially preserved, exhibiting nine teeth, the two first ones being the largest. The vertebrae were deeply biconcave, with the notochordal canal persistent. The *clavicles* and the *interclavicle* are Pelycosaurian in shape. The interclavicle especially resembles that of *Dimetrodon* as figured by Cope. Remains of scapula and coracoid are present and a number of ribs. The *humerus* is also typically Pelycosaurian. Very fine abdominal ossicles are preserved, showing that some Pelycosauria had a ventral plastron like *Sphenodon*, *Palæohatteria* and *Kadariosaurus*.

Gaudry did not make any remarks about the relationships of *Stereorachis*. Zittel³⁴ in 1888 placed it among the *Stegocephali*: "Unterordnung Stereospondyli. Vollwirbler, 1. Familie Gastrolepidoti, Bauchschupper." Lydekker^{24, 35} was the first who gave the right position to *Stereorachis*, among the *Theriodontia* in the family *Clepsydropsidae* Cope. Zittel³⁶ followed him in his *Grundzügen der Paleontologie*, 1895.

Callibrachion gaudryi, Boule and Glengeaud.⁷⁰

Callibrachion is the name applied to a very nearly perfect specimen from the Permian of Autun. It has many of the features of the Permian Reptiles and was compared by the authors with the *Palæohatteria* of Credner. That it belongs among the *Pelycosauria* there is little doubt, though the presence of procœlus and opisthocœlus vertebræ is an unwonted character in the group, and if their presence is established in the specimen may lead to a revision of its position. The authors say of the specimen, p. 15: "Le *Callibrachion* a beaucoup plus d'affinités avec le Reptile du Rothliegende de la Saxe que M. Credner a appelé *Palæohatteria*. D'après ce qui est conservé de la tête de notre spécimen, nous pouvons croire que les crânes des deux animaux étaient fort ressemblants. La division de la mâchoire inférieure en plusieurs éléments, la forme des dents, leur ordre de distribution suivant le grandeur à la mâchoire supérieure, sont des traits communs. Dans les deux fossiles les centrums étaient séparés des arcs neuraux, dépourvus d'apophyses transverses, et la notochorde persistait au centre des corps vertébraux. Les pattes étaient également bien développées et disposées sur le même plan.

"Mais à la côté de ces ressemblances, nous pouvons noter quelques différences. Les vertèbres du *Callibrachion* présentent une procœlie bien marquée et les premières vertèbres sont opisthocèles."

PELYCOSAURIA FROM THE PERMIAN OF AFRICA.

Owen³⁷ described in 1859 *Galesaurus planiceps* and *Cynochampsia laniaria* from the Beaufort Beds of the Karoo System and placed them in the family Crocodilia. In the final paper these Reptilian remains are figured but not referred to the Crocodilia. In the second edition of his *Paleontology* (1861) Owen³⁸ placed these two genera in a new, third family of the order *Anomodontia*, with the name *Cynodontia*. This is his classification:

Order *Anomodontia*.

1. Family *Dicynodontia*—*Dicynodon* Ow., *Ptychognathus* Ow.
2. Family *Cryptodontia*—*Oudenodon* Ow., *Rhynchosaurus* Ow.
3. Family *Cynodontia*—*Galesaurus* Ow., *Cynochampsia* Ow.

The family *Cynodontia* is thus characterized: "A pair of teeth in each jaw, resembling in shape, position and relative size to the other teeth, the canines of carnivorous mammals, and dividing the incisors from the molars."

Haeckel³⁹ in 1866 divides the *Anomodontia* into three families :

1. *Rhopalodontia*—*Rhopalodon*, Permian Russia.
2. *Dicynodontia*—*Dicynodon*, *Ptychognathus*.
3. *Cryptodontia*—*Udenodon*, *Rhynchosaurus*.

The order *Theriodontia* was established by Owen⁴⁰ early in 1876. It was to contain *Galesaurus* and *Cynochampsia* and the new South African genera *Lycosaurus*, *Tigrisuchus*, *Cynosuchus*, *Nythosaurus*, *Scaloposaurus*, *Procolophon*, *Gorgonops*, as well as the genus *Cynodracon*. He remarks :

“For the name of these extinct carnivorous *Saurians* I find it convenient and believe it will be generally acceptable to form a distinct order of Reptilia under the denomination of *Theriodontia*, with the following characters : Dentition of the carnivorous type ; incisors defined by position, and divided from the molars by a large lanariform canine on each side of both upper and lower jaw, the lower canine crossing in front of the upper ; no ectopterygoids ; humerus with an entepicondylar foramen ; digital formula of fore foot 2, 3, 3, 3, 3 phalanges.”

In 1878 appeared Owen's *Catalogue of the Fossil Reptilia of South Africa*.⁴¹ The Order *Theriodontia* is now defined in the following way :

“*Char.* Dentition of the carnivorous type ; incisors defined by position, and divided from molars by a large lanariform canine on each side of both upper and lower jaws, the lower canine crossing in front of the upper as in Mammalia.”

The *Theriodontia* are divided in three sections.

Section *Binaria*.

The external nostrils are divided by a narrow partition ; the entire skull has a compressed form.

Genera *Lycosaurus* Ow. Species *L. pardalis* Ow., *L. tigrinus* Ow., and *L. curvimola* Ow.
Tigrisuchus Ow. Species *T. sinus* Ow.

Fam. *Mononaria*.

In this family of *Theriodontia* the external nostril is single or undivided, and the incisors exceed three in number in each premaxillary.

Genera *Cynodracon* Ow. Species *C. serridens* Ow., *C. major* Ow.
Cynochampsia Ow. Species *C. lanarius* Ow.
Cynosuchus Ow. Species *C. suppostus* Ow.
Galesaurus Ow. Species *G. planiceps* Ow.
Nythosaurus Ow. Species *N. larvatus* Ow.
Scaloposaurus Ow. Species *S. constrictus* Ow.
Procolophon Ow. Species *P. trigoniceps* Ow., *P. minor* Ow.

Fam. *Tectinaria*lia.Genus *Gorgonops* Ow. Species *G. torvus* Ow.

In 1881 Owen⁴² described a new genus, *Ælurosaurus felinus*, from South Africa, which he considered as a member of the *Theriodontia*, belonging to the "Mononarial Section." The animal presents the elevated facial region of the *Pelycosauria*, with the convex alveolar border of the upper jaw and the posterior position of the orbits. The teeth are differentiated as in most all of the South African Reptiles. The posterior portion of the cranium is lost and was later restored by Seeley⁴³ as an elevated region. There is much more probability that it was depressed by the quick descent of the temporal bones to join the depressed quadrate as in the American forms. Only the skull of the form is known.

In this paper Owen adds certain characters to the order *Theriodontia*. He says: "To the characters of this order given in my *Catalogue of the Fossil Reptilia of South Africa*, viz., 'Dentition of the carnivorous type, incisors lanianiform, canine on each side of both upper and lower jaws,' may now be added 'dentition monophyodont.' Add to these characters 'humerus perforated by an entepicondylar foramen.'"

In 1889 Seeley⁴⁴ discussed the whole group *Anomodontia* and their relations to the other Permian Reptiles. He says of the *Pelycosauria*, p. 282: "There are few data for judging of the systematic value of the *Pelycosauria*. But in view of the fact that the *Anomodontia* was originally made to include animals which are allied to the *Pelycosauria*, supposing that group to be well founded, it seems more in accordance with usage to class these animals with the *Anomodontia* than to adopt a new name like *Theromorpha* for a well-known ordinal type.

"There is need, however, that the distinctness of the *Pelycosauria* should be established. The tibiale and the centrale are said to unite to form an astragalus which has no movement on the tibia. One face of the astragalus receives the cuboid. Subsequently an entire carpus was figured, which has a very mammalian aspect. It is regarded as referable to *Clepsydrops natalis* Cope, and is classed as *Pelycosauria*. A similar tarsus was subsequently referred with doubt to the genus *Theropleura*. It is difficult to judge of its importance. Its characters appear to be more mammalian than those of the *Crocodylian* tarsus, for the bones of the distal row are completely ossified. The tarsus is absolutely unknown in any of the *Anomodontia* from Africa, Europe and Asia; and, therefore, there is no means of comparison with the American fossil.

"The *Pelycosauria* are said to have two or three sacral vertebræ, a notochordal column and intercentra usually present. With the evidence that *Dinosaurs* may have as few as two sacral vertebræ, as well as a larger number than has been found in any *Ano-*

modont, this ground of ordinal distinction fails. Similarly the mode of ossification of the intervertebral substance presents many types among the *Anomodonts*, one of which, already figured by Sir Richard Owen, might be regarded as notochordal. What the value of the intercentra may be I am unable to say, as they have not been figured; but intercentra, as I understand them, are not unknown among the *Anomodonts*.

“The remarkable vertebral column with the elongated neural spines referred to *Dimetrodon* is apparently unlike any known *Anomodont*, but the elongation of the neural spines in certain of the Wealden reptiles, like (?) *Hylæosaurus*, is not considered to militate against their position in the group to which they belong. And it may be doubted if the more extraordinary neural spine of *Naosaurus*, with its transverse branches, has any greater classificational value, since the transverse branches are the only characters by which the author separates *Naosaurus* from *Dimetrodon*. In *Theropleura*, which is also described as having elevated neural spines, abdominal rods are found. In a further discussion of the subject the author still considers *Empedias* as a member of the *Pelycosauria*.”

In a scheme of classification given the *Pelycosauria* are regarded as a doubtful group near to *Lycosaurus* and *Dicynodon*.

In 1895 Seeley⁴⁵ divided the *Anomodontia* into three great divisions, the *Therosuchia*, *Therochelon* and the *Mesosauria* or *Proganosauria*. The *Therosuchia* is defined as follows: “The palatine and the transverse bones of the palate are produced outwards and usually downwards, in an arch, which abuts against the inner side of the mandible. This character defines the group from the *Dicynodonts*, the *Mesosaurus*, *Nothosaurus* and all fossil groups of reptiles. There are more or less completely divided heads to the dorsal ribs. A foramen of variable size occurs between the ischium and the pubis. The ilium extends on both sides of the acetabulum.”

The classification here given is as follows:

“*Therosuchia* comprise:

Parciasauria.

Procolophonia.

Gorgonopsia.

Dinocephalia.

Deuterosauria.

Placodontia.

Theriodontia { *Lycosauria.*
 { *Cynodontia.*
 { *Gomphodontia.*

Endothiodontia.

Theromora { *Pelycosauria.*
 { *Cotylosauria.*

Kistecephalia.

“*Therochelonina* comprise :

Dicynodontia.

“*Mesosauria* or *Proganosauria* :

Nothosauria (?)”

In a footnote the author says of the *Theromora* : “This group has no authority at present and is subject to future definition.”

PELYCOSAURIA FROM THE PERMIAN OF RUSSIA.

In 1838 Kutorga⁴⁶ reported the discovery of vertebrate remains on the west slope of the Ural mountains. He considered the remains to belong to mammals and thought that the rocks were of Carboniferous age. Several genera were described, *Brithopus*, *Orthopus* and *Syodon*.

In 1841 Fischer de Waldheim⁴⁷ described from the same locality a new genus, *Rophalodon*, which he characterized as follows : “Gesteilte Zähnen mit hohlen Stielen und mit soliden keulenformiger Krone. R. Wagenheimi, mit vorn gehaltenen Zähne, der kiel gezähnte. R. Mantelli, mit langsfurchten Zähne.”

In 1842 the same author described a second genus,⁴⁸ *Eurosaurus*, from the same material that had been used by Kutorga in his description of *Orthopus*.

In 1845 Wagenheim von Qualen⁴⁹ announced in a letter to Fischer the discovery of a specimen in the Russian deposits, which he considered a Carboniferous plant related to *Pecopteris*. This specimen was recognized by Fischer as a skull and described by him⁵⁰ in the *Bull. of the Soc. of Moscow* as *Dinosaurus Murchisonii*.

In 1848 Eichwald⁵¹ more fully described the forms *Rhophalodon Wagenheimi* and *Dinosaurus Murchisonii*. The latter genus he regarded as a synonym of the first. Two new genera, *Deuterosaurus* and *Zygosaurus*, were described in the same paper.

In 1857–1858 Herman von Meyer⁵² described a few forms from the Permian of Russia and later a second article discussed the same specimens more fully.⁵³

In 1860, in his *Lethæ Rossica*, Eichwald⁵⁴ described all the known genera from the Russian Permian. He regarded all the Reptilian forms as belonging in two genera only, *Rhophalodon* and *Deuterosaurus*. He gave the following classification :

Fam. *Theriodontisaurier*.

Genus *Deuterosaurus*.

Rhophalodon.

Fam. *Labyrinthodonten*.

Genus *Eurosaurus*.

Zygosaurus.

Archægosaurus.

In 1880 Twelvetrees⁵⁵ discovered a skull and humerus in the same deposits from which the earlier Russian fossils had been taken. The skull was of a Labyrinthodont which he called *Platypodosaurus*, and the humerus he referred to Owen's *Theriodontia*.

In the same year the same author described⁵⁶ the genus *Chiorhizodon*, and two years later, in an article in the *Geol. Mag.*⁵⁷ described teeth referred to the genera *Cynodraco* and *Deuterosarus*.

In 1876 Owen⁵⁸ published a review of the Permian reptiles, in which he discussed most of the Permian forms.

In 1883 Trautschold⁵⁹ described the remains preserved in the collection of the University of Kasan. Two new genera were described, *Platyops* and *Trematina*.

In 1894 Seeley⁶⁰ discussed and figured the two principal genera of the Permian deposits of Russia, *Rhopalodon* and *Deuterosaurus*. He considered that of all the forms described from this region there are only two types. He says, p. 664: "The remains with a *Theriodont* dentition show two generic types, which are indicated by the skulls. They are defined as *Rhopalodon* (Fischer, 1841) and *Deuterosaurus* (Eichwald, 1848). Kutorga had previously founded *Brithopus* on the distal end of a humerus; *Orthopus* on the proximal end of a humerus; *Syodon* was based on a tooth. Fischer in 1847 separated *Dinosaurus* from *Rhopalodon* by dental and cranial characters. It is probable that the separation was based on sufficient evidence. And, although there is no conclusive association of parts of the skeleton to support the reference, it seems to me not improbable that *Brithopus* is identical with *Deuterosaurus*. That *Orthopus* includes *Syodon*, and the type of *Rhopalodon*, while the remainder of *Rhopalodon* corresponds with the genus *Dinosaurus*, as conceived of by Fischer."

These two forms he considers as belonging to the *Anomodontia*, but constituting a separate suborder described as follows, p. 715: "The *Deuterosauria* are defined as *Anomodontia*, distinguished from the other known groups by having (1) the palato-nares divided by the vomer and without having any hard palate extending over them. (2) The canine teeth are serrated (and large) with incisor teeth in front (in *Deuterosaurus*) and molar teeth behind. There are temporal vacuities and a pineal foramen. (3) There is no facet for the head of a rib on the (middle dorsal) vertebræ, and no proof that it was attached between any two centra in any vertebræ; the tubercle is attached to the transverse process. The lower dorsal ribs have no antero-posterior expansion. (4) There are two sacral vertebræ ankylosed. (5) The ilium has a small crest without conspicuous anterior development. The acetabulum is imperforate, as in the *Dicynodontia* and the *Ornithosauria*. The limbs and the shoulder girdle are strong. (6) The scapula is flat.

The two genera appear to be the types of two distinct families, *Deuterosauridæ* and

Rhopalodontidae, distinguished by the structure of the temporal region of the skull, which has a median crest in the former, and is roofed over on the superior surface in the latter. In the former the incisor teeth are strongly developed; in the latter serrated, lanceolate molars are strongly developed behind the canines.

Deuterosaurus.

Has the skull compressed from side to side, with large transversely compressed incisor teeth. The lachrymal bone is greatly developed. The postorbital arch is deep, and situated below the orbit. The quadrate bone is large and developed below the foramen magnum on the type of *Placodus*. The vertebræ are biconcave. The ribs are long. The sacral ribs are well developed. The scapula is expanded at its free end. The pubis and ischium diverge from below the acetabulum; there is a supra-acetabular, articular wedge on the ilium.

Rhopalodon.

Has the skull more elongate and less deep, with the superior temporal vacuities roofed with bone. The orbit is relatively far back and defended with a circle of sclerotic bones. The incisors are clearly evidenced. The canines are large. The lanceolate molar teeth are of the Megalosaurian type. The vertebræ are biconcave. The scapula is concave on its borders, without conspicuous expansion at the free end. The pubis and ischium do not manifestly diverge ventrally, there may be a supra-acetabular articulation on the ilium."

PELYCOSAURIA FROM THE PERMIAN OF BOHEMIA.

In the first volume of the *Fauna of the Gascoal*, Fritsch⁶¹ described a specimen that he supposed to be a portion of the border of the pectoral fin of a fish. Later in a supplement to the third volume of the same work⁶² he recognized the nature of the supposed spine and described it as the neural spine of new species of Cope's genus *Naosaurus*, *N. mirabilis*. This is the only reptile from the Permian deposits of the Bohemian region.

In 1895 Fritsch⁶³ described new forms from the same horizon. A figure of a dorsal vertebra and spine of the same species as before described is figured. There is no description beyond the statement of the length of the spine. "Dieselben besitzen eine 13fache Länge des Wirbelkörpers und erreichen eine Länge eines *halben Meters*." It is still considered as the single reptile of the horizon.

DESCRIPTION OF THE SKELETON OF DIMETRODON.

The general shape of the skull can best be seen from the figures. There are two temporal arches; an upper, postorbito-squamosal arch, and a lower quadratojugal arch. There is, of course, also a parietoquadrate arch.

Seen from above the following openings are found in the skull: The *anterior nares*, far in front, bounded by the premaxillaries, maxillaries and nasals; the *orbits*, placed nearly vertically, and surrounded by the frontals, prefrontals, lachrymals, jugals, postorbitals and postfrontals; the *supratemporal fossæ*, bounded by the parietal, postorbital, prosquamosal and squamosal; the *infratemporal fossæ*, formed by the postorbital, jugal, quadratojugal and prosquamosal. The *pineal* foramen is placed between the parietals. The *posttemporal fossæ* are surrounded by the posterior parietal processes, the squamosal, the paroccipital processes and the supraoccipital.

The *premaxillaries* (Pl. I, Fig. 1) are small, strong, paired elements. They are suturally united in the middle line, sending a slender process between the nasals. Behind they are united with the maxillaries and at the union a deep notch is present. Their anterior edge is rounded and carried upon a slender recurved process which borders the nasal opening anteriorly and joins the nasals above. The lower portion of the opening is formed by the posterior part of the upper edge of the premaxillary, which is excavated at the base of the superior process. Internally the two bones unite at their anterior edges and show faces for the anterior ends of the vomers. There are three teeth in each premaxillary; the anterior large and strong, followed by two smaller ones. The *nasals* (Pl. I, Fig. 2n) are long and slender bones, connected with the premaxillaries, maxillaries, prefrontals and frontals. They are suturally united in the middle line, and diverging behind to enclose the pointed anterior ends of the frontals, which they overlie. Anteriorly they receive the posterior prolongations of the premaxillaries between them. Below they are united with the maxillaries and behind with the prefrontals. The *frontals* (Pl. I, Fig. 4) are paired. They are of peculiar shape. They form a very short suture with the parietals, reach in front between the posterior ends of the nasals and send out laterally slender processes which take part in the upper border of the orbit. The frontals are flat and narrow, showing that the skull was not very broad. They join the nasals, prefrontals, postfrontals and parietals. The *parietals* (Pl. I, Fig. 5) are very small and short. They are not suturally united with the supraoccipital, but by cartilage. Their posterior processes, which are first horizontal, but vertical at the distal end, join the squamosals. The parietals are connected with the frontals, postfrontals, postorbitals, squamosals, supraoccipital and paroccipital. The *prefrontals* (Pl. I, Fig. 3) are well developed; they take part in the anterior and upper border of the orbit. They join the

frontals, nasals, maxillaries and lachrymals. The whole bone is bent upon itself at a right angle, producing an upper horizontal and lower vertical portion. The posterior

Fig. 1.

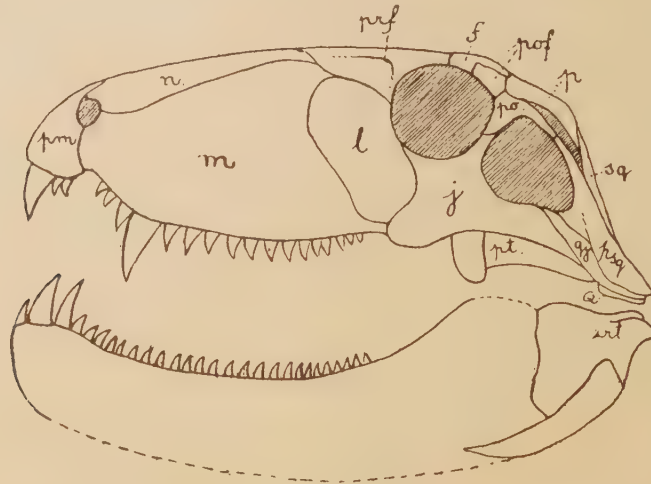


Fig. 2.

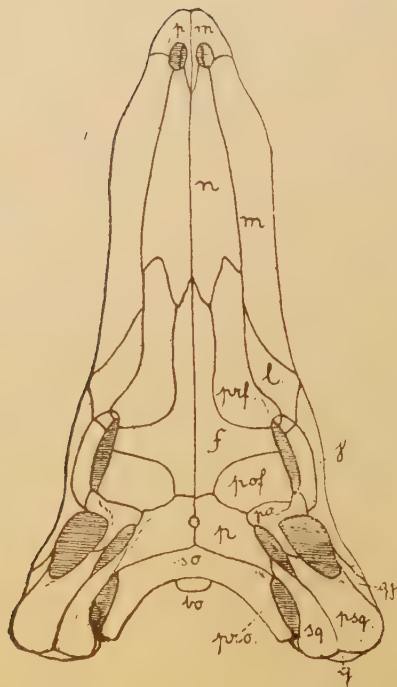


Fig. 3.

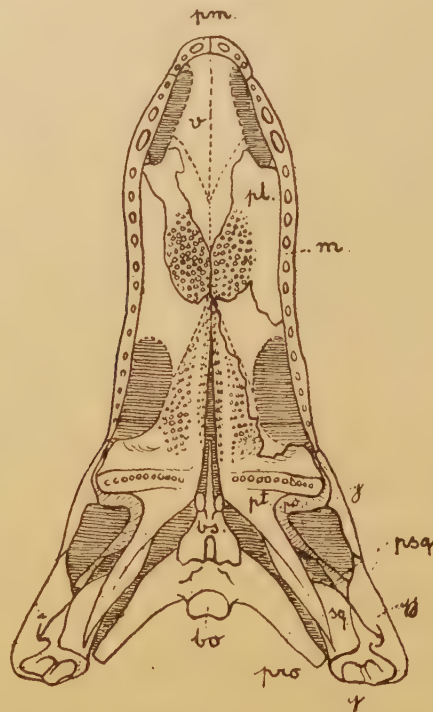


FIG. 1. Skull of Dimetrodon, Cope. Side view.

FIG. 2. Skull of Dimetrodon, Cope. From above.

FIG. 3. Skull of Dimetrodon, Cope. From below.

edge is rounded and thickened, forming the upper anterior border of the orbital rim. Just anterior to this there is a deep excavation, the preorbital pit. The bone becomes

quite thin, but there are no vacuities. The *postfrontals* bound the orbit above and are placed between the frontal, parietal and postorbital. They are approximately quadrangular in outline. Posteriorly they are joined to the postorbital by a broad flaring suture, the ridge thus formed marking the upper posterior angle of the orbital rim. The external edge, which forms part of the orbit, is thickened and rounded. The *postorbitals* (Pl. I, Fig. 7) take part in the formation of the orbit behind. They are united with the postfrontals and parietals above, send a posterior process to the *prosquamosal*. The postorbital is crescentic in outline, thin antero-posteriorly and expanded laterally. The jugal overlies a large part of the posterior surface of the lower portion and receives the lower end into a notch on its inner surface, so that the postorbital takes little part in the rim of the orbit, but forms a large part of its posterior wall. A deep groove extends on the external side between the faces for the postfrontal and jugal and notches the rim. The groove ends internally against a ridge which supports a long posterior process bearing the face for the *prosquamosal*. Internal to this ridge there is a flat slightly sigmoid face for the parietal.

The *maxillaries* are very large bones, very thin at the upper and lateral parts. They extend as thin plates far up on the side of the skull, reaching the lachrymals, prefrontals and nasals. They form a large part of the inferior and posterior border of the nasal openings. Below they become suddenly very thick to contain the deep alveoli of the teeth. This thickened portion takes the form of a strong ridge on the inner face of the lower edge and extends from the anterior end nearly to the posterior. The lower edge is gently convex downwards, anteriorly it is excavated by a deep notch, which marks the point of union of the maxillary and premaxillary. There are seventeen teeth in the maxillary. Two small ones occupy the maxillary part of the notch; succeeding this are two large teeth, one just appearing, and finally teeth nearly equal in size, but much smaller than the canine. The canine is directed nearly straight downwards, more convex on the outside than the inner and has well-defined anterior and posterior edges. The succeeding teeth are nearly uniform in size except the last few, which diminish rapidly. They are stout, quite strongly recurved and have strong antero-posterior cutting edges which are finely serrated. The maxillaries are joined with the premaxillary in front, the nasal and prefrontal above, the lachrymal and jugal behind; at the inner rounded and thickened lower part is found a very distinct suture for the palatines.

Measurements of Maxillary.

	M.
Length (nearly complete).....	0.192
Length of largest tooth from base.....	0.055
Length of largest tooth from outer edge of jaw	0.040
Breadth of the same tooth at base.....	0.019
Length of fifth tooth from outer edge.....	0.018

The *lachrymals* are large plate-like and very thin except at their posterior extremity. Here the orbital portion is thickened and pierced by one or two foramina. Below, the edge becomes very thick and strong and is inserted into the posterior edge of the maxillary. The lachrymals form the anterior lower part of the orbit. They are joined to the prefrontals above, the maxillaries in front and below, the jugals behind.

The *jugals* (Pl. I, Fig. 6) are large and take part in the rim of the orbit, forming the lower and part of the posterior edges. The rim is marked by a sharp, elevated ridge. Below it is divided into two main parts. One running forwards and downwards joins the posterior edge of the maxillary. The inner face of this arm is marked by a strong ridge bearing at its lower edge a strong articular face for the ectopterygoid. The second runs almost straight backward, becomes quite slender posteriorly and joins the quadratojugal by a squamous suture. The whole of the lower portion of the bone becomes quite thin. The upper posterior process is united with the postorbital. The jugals join therefore the following elements: In front the lachrymals, below the maxillaries, behind the quadratojugs and above the orbitals.

The *suspensorial region* of the skull is composed of four elements: the *quadrate*, *quadratojugal*, *squamosal* and *prosquamosal* (Pl. I, Figs. 8, 9, 10).

The *quadrate* is peculiarly flat and depressed. It is covered superiorly by the squamosal, prosquamosal and quadratojugal. The squamosal, reduced distally to a broad, thin plate, is joined to the upper surface by a squamous suture, covering the inner portion. Laterally it wraps around the inner edge of the quadrate and appears largely on the lower face.

The outer part of the upper surface is covered by the prosquamosal and quadratojugal joining it by squamous suture. The prosquamosal lies just external to the squamosal, but is soon separated from the quadratojugal, which is wedged in between them. Superiorly the quadrate sends a process forward which extends between the squamosal and prosquamosal. The anterior end of this projection is incomplete, but possibly was continued forwards to join the posterior plate of the pterygoid. The outer edge of the projection is marked near its origin by a deep pit extending between the quadrate and quadratojugal. It represents the foramen between the quadrate and quadratojugal in *Sphenodon*, *Phytosaurus* (*Belodon*) and *Ichthyosaurus*.

The articular face for the lower jaw consists of two grooves lying at a large angle to the main axis of the skull. The outer is the longest and deepest, the inner wide and more shallow. They extend across the inferior face of the bone from before backwards, and are separated by a ridge as high as the external walls.

The *quadratojugal*, as shown by the articular face on the posterior process of the jugal, sent a strong process forwards. Posteriorly the inner edge extends as a wedge

between prosquamosal and the quadrate. On the inferior surface a strong process runs inwards and covers a part of the external edge of the quadrate. This process is notched by the deep pit already described. Anteriorly the bone became very thin and underlay the prosquamosal for quite a distance.

The *squamosal* joins the quadrate as already described. Externally it joins the prosquamosals, the two bones meeting with everted edges to form a narrow ridge. The cranial end of the squamosal was connected with the distal ends of the parietals by a narrow squamous suture.

The *prosquamosal* has been very largely defined in describing the other bones. The superior surface is marked by a prominent ridge, which curves forwards and inwards until it overhangs the ridge formed at the union of the squamosal and prosquamosal. The anterior process became very slender and narrow and joined the posterior prolongation of the postorbital, thus forming the upper temporal arch so characteristic for the *Rhynchocephalia* and the whole group of *Archosauria*.

The bones forming the *cranium* are all preserved, free from distortion and in their natural position. The whole region resembles *Sphenodon* in many particulars, but the obliteration of many of the sutures makes it impossible to compare exactly the separate elements (Pl. I, Figs. 11–14). The *cranium* is formed by the union of the basioccipital, exoccipitals, supraoccipital, the petrosals and the very large paroccipitals. The basisphenoid is completely free from the basioccipital. The connection was, without any doubt, by cartilage.

The *basioccipital* forms the lower half of the occipital condyle. The lower part of the condylar portion is rounded, and the upper comes to a sharp point between the exoccipitals. The point of union between the three bones is marked in some specimens by a deep pit, the anterior prolongation of the chordal canal. The lower surface is converted into a shallow groove by two descending flanges of bone. These meet laterally two other flanges from the paroccipitals, and the suture line is marked by a sharp constriction. Anterior to the trough described the lower surface of the bone rises at an angle of nearly ninety degrees. This face is excavated near its centre by a funnel-like depression, at the base of which lies the foramen for the Eustachian tube, as in the *Crocodylia*. This region is greatly swollen and contains the *petrosals*, though the sutures are entirely obliterated.

The *exoccipitals* form the borders of the foramen magnum, the basioccipital being excluded by their union below. The superior portions are very slender, and form only a narrow surface around the foramen. Inferiorly they become larger and form the superior half of the occipital condyle. They are pierced near their posterior edge by the condylar foramina.

The *supraoccipital* takes no part in the borders of the foramen magnum, being excluded therefrom by the union of the exoccipitals in the median line above the opening. It is somewhat triangular in outline, with the apex downwards. This is somewhat blunted and rests on the united exoccipitals. The sides join the expanded proximal ends of the paroccipitals. The superior border consists of a broad surface for cartilaginous attachment with the parietals.

The *paroccipitals* are very broad and massive proximally, but are produced in long distal processes. These processes project at a large angle from the posterior region of the skull and pass obliquely backwards, downwards and outwards. The distal articular surface is flat or slightly concave, oval in outline, and probably united to the quadrate by cartilage. The lower surface of these paroccipital processes is marked by two deep pits, separated by a sharp ridge. The proximal portion of the paroccipital is much expanded; above they are in union with the sides of the supraoccipital and bear at the superior edges winglike expansions for the parietals. Below they are suturally united to the exoccipitals and basioccipital. The lower portions of the proximal ends give rise to two descending flanges already described as joining the basioccipital. The region anterior to this flange is deeply excavated and open, so that the foramen rotundum and ovale are freely exposed.

Measurements of the posterior cranial region.

	M.
Distance between distal ends of paroccipitals.....	0.122
Distance between ends of paroccipital processes.....	0.112
Breadth of foramen magnum.....	0.014
Height of foramen magnum.....	0.009
Breadth of occipital condyle.....	0.022
Height of occipital condyle.....	0.016
Distance from top of supraoccipital to lower edge of condyle.....	0.063

The *basisphenoid* (Pl. I, Figs. 13, 14) is broadly expanded posteriorly and contracts rapidly as it passes forwards, forming a neck just behind the closely approximated faces for the pterygoids, and ends anteriorly in a presphenoidal rostrum. The expanded posterior is marked on its upper edge by a pit, the continuation in the basisphenoid of the Eustachian canal. The centre of the posterior face is prolonged backwards in a spout-like process which lays in the groove described as marking the lower face of the basioccipitals. The lower edge of the expanded part is divided by a deep and long notch which ends abruptly anteriorly.

The basipterygoid processes are near the middle of the basisphenoid. They are short and stout, and in the natural position of the bone were nearly vertical, but directed slightly outwards, downwards and forwards. The upper part of the articular faces is

reflected backwards, forming small facets looking up and out. Between the pterygoid processes a slender presphenoid rostrum rises and projects far forwards. This rostrum is thin laterally, expanded vertically, smooth and straight on the lower edge, roughened above.

The foramina perforating the cranial region and the brain.

The foramina penetrating the bones of the cranium in *Dimetrodon* are remarkably similar in position to those penetrating the same bones in *Sphenodon*. The condylar foramen transmitting the twelfth pair (hypoglossus) penetrates the exoccipital just anterior to the edge of foramen magnum. Its outer end opens in a notch (the *incisura venæ jugularis* Sieb.) in the side of the exoccipital. A little below and further forwards a second and much smaller foramen opens in the same notch; this may transmit either the ninth or tenth pair of nerves or a minor blood vessel. Passing forwards the notch deepens and is very soon converted into a foramen by the adjacent portion of the paroccipital. This is the *foramen venæ jugularis* of Siebenrock,⁶⁸ and transmits the jugular vein and either the ninth or tenth nerves or both of them. In *Sphenodon* the foramen transmits not only these but the twelfth pair as well, the nerves being separated from the vein by very thin walls of bone, and may be separated from each other or have a common canal. The opening of the twelfth pair into the notch which forms the beginning of the jugular foramen is then very similar to the condition found in *Sphenodon*.

The fenestra ovalis, Fig. 6, *F. O.*, is a single opening leading by a very short canal directly into the brain cavity, a character found in fishes and the amphibian *Menopoma* and existing imperfectly in some recent Reptilia, as the turtles. The same thing is described by Cope as existing in another Permian reptile, from the same horizon as the present specimen, but belonging to a separate family, the *Diadectidæ*, and his order *Cotylosauria*.⁶⁹

The foramina for the seventh (facial) pair of nerves appear on the outer surface of the petrosal just anterior to the fenestra ovalis (Fig. 6, 7). They are located relatively a little further back than in *Sphenodon*. On the inner face of the same bone the foramina appear at the side of the base of the brain cavity a little anterior to their external opening. They are located just anterior to a slight ridge which defines the limits of the tympanic cavity. In *Sphenodon* this is about the point of location of a foramen common to the seventh and eighth nerves, which, however, almost immediately divides, the posterior branch penetrating the inner wall of the tympanic cavity and leading the auditory nerve to the inner ear.

The foramen for the fifth (trigeminus) nerve is completed from the incisura oto-

sphenoidea by the membranous wall of the anterior portion of the brain case, as in *Sphenodon* and many lizards (Fig. 5, 6).

The deep pit excavating the lower surface of the basisphenoid is in all probability the lower opening of the Eustachian tubes. In most reptilian forms the tubes pass into

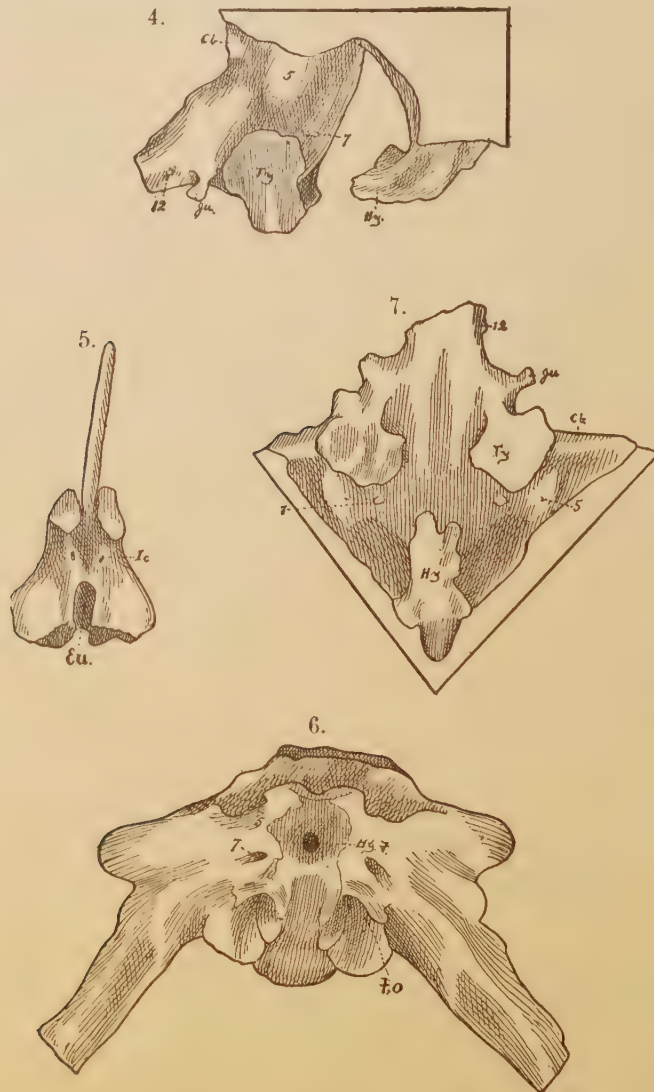


FIG. 4. Side view of a cast of the brain cavity.

FIG. 5. Lower view of the basisphenoid.

FIG. 6. Lower view of the cranial region.

FIG. 7. Lower view of the cast of the brain cavity.

5. The trigeminus nerve. 7. The facial nerve. 12. The hypoglossus nerve. *Ju*. The jugular foramen. *Ty*. Cast of tympanic cavity. *Hy*. Hypophysis. *Hy.F*. Foramen penetrating base of basioccipital. *F.O*. Fenestra ovalis. *I.C*. Foramina for internal carotids. *Eu*. Opening of eustachian tubes. *Cb*. Cerebellum.

the pharynx in the neighborhood of the basioccipital-basisphenoid suture and anterior to the fenestra ovalis. In the Crocodilia and the aglossal batrachians they have a common

opening into the mouth. In the present form the tubes probably penetrated the large mass of cartilage covering the otic region and the posterior end of the basisphenoid and found a common opening in the deep pit described. It is difficult to imagine the use of such an extensive cavity in the basisphenoid, but in the *Teleosauria* an equally large cavity is found roofed over with bone. Anterior to this pit two foramina, Fig. 5, *I. C.*, penetrate the lower surface of the basisphenoid bone and on its upper surface a large foramen appears just posterior to the origin of the presphenoid rostrum. Through the pair on the lower surface the internal carotid arteries enter the bone and through the upper it gains access to the brain cavity by way of the pituitary fossa. On either side of the single foramen a pair of small foramina carry branches of the internal carotid. All of these foramina are very similar in position to the same ones in *Sphenodon*.

The cast of the brain cavity shows fairly well all parts posterior to the fifth pair of nerves, and the hypophysis anterior to them. As is well known, the brain in the Reptilia does not fill the brain cavity, but is supported by a mass of connective tissue carrying lymph and fat masses, so a cast of the brain cavity does not give an exact copy of the brain; however, many points can be brought out by such a cast.

If the cast be held with the short terminal portion of the medulla horizontal, the lower surface pitches downwards at a sharp angle to a point anterior to the tympanic region and then ascends as sharply to the point of origin of the hypophysis. The superior surface is horizontal and arched from side to side to a point over the tympanic cavity and there turns upwards at an angle of 45° . The angle thus produced is marked by a low, narrow ridge running across the cast and marking the position on the brain of a narrow and elevated cerebellum, Figs. 4 and 7, *Ob.*, such as occurs in *Sphenodon*. This region was probably the seat of a large amount of connective tissue, and it is probable that the upper surface of the medulla descended at as sharp an angle as the lower. This would make still more marked the resemblance to *Sphenodon* and to the cast figured by Cope. This sharp bend of the medulla downwards is not found in other forms, though in the brain of *Chelonia* and some *Lacertilia* a bend is apparent.

The sides of the medulla show most posteriorly the beginning of the twelfth nerves, Figs. 4 and 7 (12), anterior to these the cast of the jugular foramen, Figs. 4 and 7, *Ju.*, and finally the large casts of the tympanic cavity, Figs. 4 and 7, *Ty.* The nature of the matrix and the cavities prevented the tympanic cavities being cleaned so that the semicircular canals could be determined, but it is probable that they were very similar to those described by Cope.

Anterior to the tympanic casts a sharp constriction marks the ridge defining the limits of the tympanic cavity and then a sharp outswelling the point of exit of the trigeminal nerve, Figs. 4 and 7 (5). Near where these leave the body of the cast a small stub on each side marks the origin of the seventh pair, Figs. 4 and 7 (7).

The hypophysis is the most interesting feature of the brain. Descending between the anterior inferior process of the petrosal and turning posteriorly, it occupies a small notch in the posterior edge of the upper surface of the basisphenoid and then passes directly into the body of the basioccipital through the foramen mentioned. In the *Crocodylia* a somewhat similar condition exists. The basisphenoid is excavated for a considerable extent to accommodate the hypophysis. This makes it probable that the excavation of the bone is merely a secondary character to make room for the hypophysis, for in the *Crocodylia* the basisphenoid takes a large part in the floor of the brain-cast, and in the present form it is pushed so far downwards that it is excluded and the hypophysis encounters the basioccipital as soon as it turns toward the rear.

Marsh^{64, 65} has described in the family *Atlantosauridae* of his suborder *Sauropoda* of the *Dinosauria* a condition in which the pituitary cavity becomes a canal perforating the basisphenoid and opening into the pharyngeal cavity, considering it an embryonic character such as exists in the chick at the fifth day of incubation.

If the hypophysis occupied the entire cavity in the basioccipital it extended back nearly as far as the tympanic region and much further back than in most reptilian forms. In *Sphenodon*, the *Crocodylia* and some amphibians it reaches well back, but not so far as in the present form.

Compared with *Sphenodon*, the specimen shows the following points of resemblance. The foramina for the blood vessels and nerves are almost identical in position and nature. The contour of the medulla and cerebellum was similar and the hypophysis extended far back. The only point of difference is the excavation of the basioccipital to receive the distal end of the hypophysis. The free communication of the tympanic cavity is a character which is found in many existing primitive forms and is of secondary importance.

The points here brought out confirm the close relationship of *Pelycosauria* to the primitive *Rhynchocephalia* already asserted by Baur and Case.²⁸

The Palate.

The following elements of the palatal region are preserved: both the pterygoids (the left nearly complete), the palatine of the left side, lacking the posterior portion and parts of the right one. No traces of the vomers have been found.

The *pterygoids* (Pl. I, Figs. 15, 16) are large bones which show three processes; an anterior horizontal one, becoming very thin in front and underlying the palatines; a posterior one, forming an extensive vertically expanded plate, and an external very massive ectopterygoid portion. The posterior plate leaves the massive part by a roundly trihedral neck; its lower edge runs downwards and backwards to the quadrate. The upper

edge is folded upon itself, forming a long and deep pit on the outer side. The edge is continued backwards horizontally, or even rising a little for nearly half the extent of the plate, and then falls off rapidly to join the inferior edge in a sharp point. The middle of this posterior edge is marked by a notch. It is possible that an anterior prolongation of the quadrate overlapped this part of the pterygoid, as it does in *Sphenodon*.

The massive part stands out from the plate-like portions; supported by a rather stout neck, it expands distally and its external face extended below the line of the teeth and formed an opposing process to the coronoid of the lower jaw. The upper end of the distal portion is injured on both sides, but probably bore a face for the *ectopterygoid*, which must have been present, as there is a distinct face for such a bone on the inner face of the jugal where it meets the maxillary. The ventral edge of the ectopterygoid process is rounded and bears eleven comparatively large teeth, which are placed in distinct alveoles and replaced from behind.

The anterior part is horizontal, the inner edge excepted, which is turned vertically upwards. The inner edges were close together and were united in the anterior part. The lower portion is covered nearly completely with small conical teeth—those on the outer and posterior region are the largest. A groove extends between this tooth-bearing region and a ridge marking the origin of the vertical plate. There are a few small teeth in the groove, and the ridge also bears a series of small teeth.

The pterygoids articulate with the basisphenoid processes just posterior to a point opposite the union of the ectopterygoid processes with the plate-like part. There are no faces on the pterygoid corresponding to those on the basisphenoid processes. The union must have been by ligament. The connection between the posterior processes with the quadrate was also ligamentous.

The *palatines* are strong bones, becoming more slender posteriorly. They are connected with the maxillary by their entire external edge by suture. The articular face is broadened and vertical. The inner portion of the ventral side of the palatines is covered with small conical teeth. The region bordering the posterior nares is preserved and determines their position, their posterior ends being just behind the large canine tooth.

The *vomers* are not preserved, but there are two small faces at the middle portions of the posterior line of the premaxillaries showing where they were attached. They were probably long and slender, paired and covered with small tubercular teeth. That the vomers were directly connected behind with the anterior processes of the pterygoids, excluding the palatines from the middle line, is very probable.

The *lower jaw* is represented by three bones—the *articular*, coössified with the *angular*, the *dentary* and a third bone, probably the *supra-angular*. The *dentary* contains twenty-seven teeth, which are located on a thickened ridge in alveoles. The first tooth is

slender and conical, slightly recurved. The succeeding two are nearly as large as the canine above; the remaining teeth are all small and recurved. The lower edge of the dentary is thin and marked internally with strong suture lines. The symphysis is short.

The Vertebral Column.

The vertebral column is represented by cervicals, dorsals and caudals.

The cervical vertebræ. The following cervicals are preserved: The atlas, with the exception of the neural arches, the axis, the third, the sixth, the seventh and the eighth. Two vertebræ, the fourth and fifth, are missing.

The *atlas* (Pl. II, Fig. 20). The centrum is broad above, antero-posteriorly, but below it is much contracted between the first and second intercentra. The anterior face is divided into an upper and lower part by a compression of the sides opposite the opening of the chordal canal. The lower part is saddle-shaped, and the upper somewhat convex. There are no traces of transverse processes. The posterior face is hidden by the second intercentrum and the axis, but another specimen shows a large opening of the chordal canal, in contrast to a very small one on the anterior face.

The *first intercentrum*, forming the lower piece of the atlas ring, is crescent shaped, with a broad lower rugose surface and a transverse concave keel above. The anterior face of the intercentrum is the largest, concave vertically and transversely, and lodges the lower part of the occipital condyle. The posterior face is convex from above downwards and occupies the saddle-shaped lower half of the anterior face of the atlas. The first intercentrum shows at the distal end below a facet on each side for the articulation of the single-headed atlas ribs.

The *second intercentrum* is similar to the first; the anterior and posterior faces are more equal. It is wedged in between the centra of the atlas and axis, and has the facets for the capitula of the axis ribs placed more to the middle of the posterior edge.

In the *axis* the centrum is well developed; on the ventral side a keel begins to appear. The posterior face of the neural spine is greatly expanded vertically at the base and greatly elevated. The posterior edge of the spine is thickened and divided by a groove which forms a deep cavity between the well-developed zygapophyses below. The apex is marked by a shallow triangular depression. The præzygapophyses are very small, with the articular faces directed downwards. The postzygapophyses are strong and elevated above the centrum. The articular faces look outwards and downwards and meet on the summit of a short keel below. The transverse processes project laterally and ventrally from the anterior part of base of the neural arch. The distal end does not become separated from the body of the neural arch, and is above the neuro-central suture.

The *third cervical* is badly injured by decay, but many points can be made out. The

articular faces are nearly round. The transverse processes curve outwards and downwards as in the axis, but the distal end reaches much further ventrally and is below the neuro-central suture for about a centimeter. The spine rises vertically from the centrum to a height of .147 m. It is broad and stout at the base, but suddenly contracts a short distance above it and ends in a slender rod curved slightly forwards. Between the bases of the præzygapophyses and the spine depressions exist, which become deep elongated pits in the dorsals.

Now follows a gap of two vertebræ. The *sixth* has a cylindrical body and round articular faces. The lower edges of the faces are extended ventrally, forming a slight flange or apron, which becomes very prominent in the posterior dorsals. The middle portion of the anterior edges on each side are reflected, forming an articular face. The transverse processes are short and stout, and stand out directly from the body of the neural arch. The articular face looks outwards and slightly backwards. From the anterior edge of the face a narrow process, bearing an articular face, runs down to the face on the anterior edge of the centrum. This shows that in the cervical region the capitulum and tuberculum of the ribs were still united.

The transverse process stands well above the centrum. There is a deep excavation at its base, running back to the notch between the posterior zygapophyses and the posterior edge of the centrum. This is interrupted near its middle by a ridge running up to the posterior edge of the transverse process. Superiorly the transverse process joins immediately the præzygapophyses, which are interrupted by a deep notch near their base. The articular faces of the postzygapophyses look outwards and downwards and meet on a small keel below. The faces of the præzygapophyses look inwards and upwards, and are slightly cupped.

The spine is thin at the base and somewhat elongate antero-posteriorly, with a thin, prominent ridge running up the anterior and posterior edges. A few centimeters above its origin the spine becomes rounded and then flattened antero-posteriorly. The ridges of the lower part disappear on the rounded part and are replaced by shallow grooves above. The spine has already reached a great height. The part preserved measures .385 m. in height, but this is only one-half of the spine.

The *seventh* and the *eighth cervicals* (Pl. II, Figs. 21, 22) differ only in degree from the *sixth*, the transverse processes become more slender and the face connecting the tubercular and the capitular faces nearly disappears. The pits above and below the transverse process become deeper and the body of the centrum is more compressed.

The *first (?) dorsal* is marked by a total disappearance of the capitular face on the anterior edge of the centrum. The centrum is a little higher and longer than broad. The ends of the chordal canal have broad funnel-like openings with flaring edges; the

canal becomes very small in the middle portion. The descending flange at the lower edge of the articular face has become much deeper than in the cervicals. The distal end of the transverse process has disappeared, but the base shows that it stood well out from the body of the neural arch. The slender process from the tubercular to the capitular face is still present, but incomplete at the proximal end, it still bears a small facet. The pit between the base of the transverse process and the base of the spine has become very long and deep, its anterior end is closed as abruptly as the posterior by the rising of the connection between the anterior end of the base of the transverse process and the præzygapophysis. The excavation below the transverse process is partly filled by a swelling out of the base of the neural spine and is contracted into a pit at a point posterior to the base of the neural spine. At the base of the præzygapophysis, the anterior edge of the centrum supports two small processes, one on each side of the neural canal. These correspond to similar processes on the posterior edge of the preceding centrum. The spine is nearly complete, its shape is the same as described in the cervical region, a plan which persists throughout the whole series of vertebræ. The spine is .872 m. long, or a little over twenty-five times the greatest diameter of the centrum.

The *second dorsal* differs from the first in a slight intensification of the characters.

The *third* and *fourth dorsals* are incomplete and injured by decay. A concavity of the sides of the centrum below the level of the chordal canal renders the keel quite thin and prominent.

The *fifth dorsal* shows a complete transverse process on the right side. The base presents a pinched appearance due to the presence of two deep pits, one above and the other below the base of the process. The anterior edge of the process has become broad and is marked by a deep groove. The tubercular face looks backwards and downwards, it is broad above and sharp below; from this sharp, lower, edge a narrow face runs down and inwards for a short distance, it is the remnant of the face connecting the tubercular and the capitular faces in the cervicals. The anterior and the posterior faces of the centrum are inclined slightly toward each other below and the vertical profile is slightly sigmoid, convex opposite the opening of the chordal canal and concave below it. This leaves quite a space between the lower edges of the opposing vertebræ to accommodate the intercentrum. The flanges descending from the lower edges of the articular faces have become quite broad vertically and the excavation of the lower half of the centrum is deepened so that the keel is thin and prominent. The edge of the keel is concave. The spine is incomplete, but even in its imperfect state over twenty-one times the greatest diameter of the centrum.

The *sixth dorsal* (Pl. II, Figs. 23, 24) shows a very slender base for the transverse

process; the pits above and below it are deep and the supporting ridges are slender. The process stands out nearly straight from the base of the spine.

The *seventh dorsal* closely resembles the sixth. The spine is practically complete; it is over twenty-four times the greatest diameter of the centrum with a length of .830 m.

The *eighth dorsal* shows a marked change in the transverse process which is directed forwards instead of straight outwards or backwards as in the anterior ones of the series. The distal end reaches in front of the anterior end of the centrum. The articular face for the tuberculum looks forwards and downwards, the face which formerly ran to join the capitulum has become a short process extending from one side of the tubercular face. The excavations of the side of the centrum have involved more than one-half of the vertical height, limiting the rounded part to the walls of the chordal canal. The descending flange of the articular face occupies fully one-third of their height and the edges have become very thin. The profile retains the sigmoid outline. To the anterior face of the centrum is attached the slightly displaced intercentrum. It is crescentic in outline and narrow from before backwards. The upper, concave part is divided into two nearly equal faces for the adjoining vertebræ. The lower surface is rugose and the upper posterior edges bear well-defined facets for the capitula of the ribs.

The *ninth dorsal* (Pl. III, Fig. 40) preserves both transverse processes entire. The connecting face between the capitular and the tubercular faces has entirely disappeared on the left side and is very small on the right. The upper edges of the anterior faces of the transverse processes have expanded forwards to join the prezygapophyses and roof over a deep pit below. The spine is nearly perfect. It ends in a slightly expanded rugosity. It is .863 m. long, or twenty-six times the greatest diameter of the centrum.

The *tenth dorsal* (Pl. II, Figs. 25, 26) has a more compressed body, the base of the transverse process is thin and expanded anteroposteriorly. The process curves forwards and reaches well in front of the anterior edge of the centrum. The posterior end of the centrum extends below the anterior end and causes the keel to slant toward the rear.

The *eleventh dorsal* has a very deep and narrow keel. The descending flanges on the faces of the centra take up nearly one-half of the vertical height. The posterior articular face extends below the anterior, giving the same oblique direction to the keel as in the preceding vertebra. An intercentrum belonging either at the posterior or the anterior end of the vertebra shows two well-developed faces for the ribs.

This is the last of the well-preserved dorsals. Posterior to the eleventh are five vertebræ that are badly injured by decay. In all of these the keel is very sharp and is inclined toward the rear. In the next to the last the anterior face is steeply inclined to the rear as it descends. The last two show round articular faces with only a very short

descending flange. Two intercentra preserved are broad and less completely crescentic; they still show large faces for the capitula of the ribs.

There is no trace of vertebræ from the sacral region.

Five *anterior caudals* are preserved (Pl. II, Figs. 27, 28, 29). They have rounded articular faces with broad funnel-like openings of the chordal canal. The præ- and post-zygapophyses are somewhat elevated on the broad neural arches. The ribs are articulated to both the neural arch and the anterior edge of the centrum. The division is not complete into a capitulum and a tuberculum, but a deep groove on the posterior side of the proximal end nearly accomplishes this. They are doubtless free in the most anterior caudals. The ribs are short and slender. Those most anterior are the longest and leave the vertebra by a strong curve upwards. The distal end of each rib well below and in front of the anterior end of the centrum. The keels are low and rounded. The spines are incomplete, but were not, in all probability, so much elevated as in the dorsal series. The three most anterior of the preserved caudals are in the natural position and show that there was a considerable space between the lower edges of the centra. The spaces were filled by flattened intercentra with no facets for rib articulation; they were however attached ligamentously to the capitular head of the rib as this projected free from the edge of the centrum.

Several small vertebræ are preserved from the distal end of the caudal series. They are slender and cylindrical, biconcave and without spines or transverse processes. The gradual reduction of the series shows that the animal must have had a long and slender tail.

The *scapula* (Pl. III, Fig. 30) is falciform in outline. The body is elongate, expanded and quite thin distally. It is so bent upon itself near the proximal end that the main portion lay, in life, more nearly parallel to the vertebral column than perpendicular to it. The lower edge of this portion is concave upwards. The bone is very thin distally, but becomes thickened toward the middle of the shaft, due to the presence of a strong ridge running back from the posterior edge of the humeral face to lose itself on the distal end. A foramen penetrates the shaft just below the beginning of this ridge. The anterior and superior edges are injured by decay and are incomplete. Cope figures the anterior and the superior edges as nearly straight and as meeting at nearly a right angle. He also figures a face for the clavicle near the distal end. The scapula and the coracoid contribute about equally to the deep, obliquely placed cotylus for the humerus. The edges of this cavity are marked by two strong projections, the upper, belonging to the scapular portion of the region, looks forwards and downwards and the lower, the coracoid portion, looks backwards and upwards. The portion of the scapula bearing this face lies at almost a right angle to the rest of the bone.

The *coracoid* (Pl. III, Fig. 30) is small, quadrate in outline, with a thin anterior edge. The lower edge is thickened and deeply notched near its posterior angle. The portion anterior to the notch was considered by Cope as the procoracoid. The posterior edge is concave from behind forwards and becomes swollen in the region of the scapular articulation. The union of the scapula and the coracoid was accomplished only late in life and was probably never perfect.

Measurements.

	M.
Total length of scapula and coracoid .....	.276
Total length of coracoid.....	.067
Total breadth of coracoid.....	.058
Total breadth of distal end of scapula.....	.103
Greatest extent of humeral face.....	.069

The *femur* (Pl. III, Figs. 36, 37) is a strong and heavy bone, with well-developed articular surfaces. The proximal end is rounded posteriorly and deeply excavated anteriorly so that it is crescentic in section. There is no distinct head, the whole proximal end being rounded and thickened. There is a strong rugosity near the outer part of the convex posterior surface. The shaft is roundly quadrate in section. The distal end is divided by a deep groove into two strong rugosities, both bearing articular faces. The inner is the shorter and extends inwards at a small angle to the shaft. The articular face is almost entirely on the posterior surface and looks more backwards than downwards. The face is elongated vertically and notched on its inner edge by an extension of the popliteal space. The outer tuberosity is longer than the inner and is directed downwards. It bears two articular faces, one on the posterior surface, looking almost directly backwards, is nearly square in outline, the other is apparently for the head of the fibula; it is largely on the lower surface of the tuberosity and joins the posterior face by a narrow neck near its external side.

Measurements.

	M.
Total length.....	.220
Breadth of proximal end.....	.073
Breadth of distal end across condyles.....	.069
Greatest diameter of shaft at centre.....	.036

The *humerus* (Pl. III, Fig. 32) is without prominent condyles at the proximal end. The articular face is a wide, concave area lying across the laterally expanded proximal end at nearly a right angle. The inner angle of the proximal end is expanded into a prominent tuberosity. The outer angle is thin, flattened antero-posteriorly and continuous with the strongly developed deltoid ridge. The ridge stands at almost a right angle with the proximal end of the bone. It becomes very prominent with a rugose surface

and ends below by recurving sharply to the shaft. The lower end does not lose itself entirely on the shaft, but remains as a low ridge running down and inwardly to form part of the bridge over the entepicondylar foramen.

The distal end is expanded at nearly a right angle to the proximal end. The ulnar condyle is rounded, smaller than the radial, and somewhat diagonally placed on the outer extremity of the distal end. The face is unequally divided into two facets by a low ridge. There is no deep anconeal pit on the posterior face of the bone. The radial condyle, largely on the anterior face of the bone, is divided into a prominent, rounded external portion and an inner saddle-shaped portion. The inner portion bears no articular face, but is prominent and rugose. The entepicondylar foramen is situated near the upper part of this inner expansion and is enclosed by a strong bridge, the extension of the ridge upon the shaft of the bone. Above the ulnar condyle a deep notch represents the ectepicondylar foramen.

Measurements.

	M.
Total length.....	.181
Greatest breadth at distal end.....	.117
Greatest breadth at proximal end.....	.096
Diameter of shaft at centre.....	.024
Projection of deltoid ridge.....	.035

The *ulna* (Pl. III, Figs. 34, 35) is a slender bone, somewhat longer than the humerus, with a flattened shaft. The shaft becomes gradually smaller toward the distal end and then expands slightly again. The proximal end is excavated on its anterior face by a deep fossa looking, in the natural position of the bone, upwards as well as forwards. This cavity is divided by a low ridge into two facets, the larger looking forwards and the smaller and external one looking slightly outwards. This cavity is carried onto the upper face of the bone and divides the inner and outer portions of the proximal end. These extremities are produced above the articular face and form the olecranon process. The outer is the largest and curves inwards, presenting a convex, rugose surface. The distal end of the bone is divided into two distinct articular faces.

Measurements.

	M.
Total length.....	.202
Greatest breadth at distal end.....	.037
Greatest breadth at proximal end.....	.055

The *radius* (Pl. III, Fig. 33) is curved and shorter than the ulna. The shaft is lenticular in section with the edges becoming sharp and prominent toward the distal end. The proximal end is expanded and the articular face for the humerus is deeply concave

and somewhat crescentic in outline. The distal end is less expanded and the single articular face is a shallow pit, oblong in outline.

Measurements.

	M.
Total length.....	.146
Greatest breadth proximal end.....	.042
Greatest breadth distal end.....	.038

The *tibia* (Pl. III, Figs. 38, 39) is greatly enlarged proximally. The shaft is slender and curved and the lower end is only moderately expanded. The cnemial crest is a strong ridge separated from the body of the bone by a deep fossa opening on the outer side. The fossa is continued onto the upper side of the bone as a deep pit which divides the articular face into two unequal halves, connected at their inner ends. These halves are again divided by a low trochlear ridge running fore and aft. On the posterior surface of the bone below the outer or fibular edge of the proximal end there is a strong, rounded swelling. The distal end is semicircular in outline, flattened before and rounded behind. There is no indication of a division of the distal end into articular facets.

Measurements.

	M.
Total length.....	.177
Breadth upper end from side to side .....	.072
Breadth upper end from before back.....	.051
Greatest diameter of shaft at centre.....	.021
Greatest breadth of distal end .....	.044

CONCLUSIONS.

The description here given of the genus *Dimetrodon*, together with the described characters of the forms mentioned in the historical review, enable a fairly complete characterization of the *Pelycosauria* to be given.

Teeth differentiated into incisors, canines and molars. Generally a diastema between the posterior incisor and the canines. The teeth without lateral cusps, but with the edges frequently serrated. The anterior incisors and the canines of the upper jaw much larger than the other teeth. The diastema in the upper jaw marked by a more or less deep pit at the point of union of the premaxillaries and the maxillaries. The alveolar edge of the upper jaw convex downwards and of the lower jaw concave upwards. The facial region greatly elevated by the expansion of the upper part of the maxillaries and the lacrymals. The region is quite narrow from side to side. The orbits large, round and located far back in the skull. The skull abruptly truncated posteriorly. The posterior aspect

of the skull, formed by a nearly vertical plate, concave from side to side, formed from the union of the exoccipitals, the supraoccipital, the basioccipital and the paroccipitals, the whole bearing a strong resemblance to the same region in *Dicynodon*. The upper and lower temporal arches both present; very short in the antero-posterior direction. The parietal and the superior arch descend rapidly to join the posterior end of the lower arch. The superior temporal vacuity much smaller than the lower. The quadrate greatly depressed and nearly enclosed by the surrounding bones. The lower face of the quadrate marked by two deep parallel grooves which received two corresponding processes on the articular bone of the lower jaw, thus limiting the motion of the lower jaw to the vertical plane. The nares open directly into the mouth at the anterior extremity. The pterygoids, palatines and vomers are covered by many small teeth. The ribs are two-headed in the dorsal region, the capitulum attaching to the intercentrum preceding. The neural spines of the vertebræ elevated or not. Limbs very short and strong. The humerus with an entepicondylar foramen and a notch representing the ectepicondylar foramen. The hind foot possessing both calcaneum and astragalus. A free centrale in the tarsus.

Under the *Pelycosauria*, as here defined, it seems possible to place with a considerable degree of certainty forms from all the regions which have furnished Permian vertebrate fossils. The following are the genera comprising the group as well as can be made out at present:

American forms:

<i>Clepsydrops.</i>	<i>Metarmosaurus</i> (doubtfully distinct).
<i>Dimetrodon.</i>	<i>Archæobolus</i> (doubtfully distinct).
<i>Embolophorus.</i>	<i>Lysorophus.</i>
<i>Theropleura</i> (doubtfully distinct).	<i>Naosaurus.</i>

Bohemian forms:

Naosaurus.

French forms:

<i>Calibrachion.</i>	<i>Stereorachis.</i>
..... (?)	

Russian forms:

<i>Deuterosaurus.</i>	<i>Oliorhizodon</i> (?).
<i>Rhophalodon.</i>	

South African forms:

<i>Elurosaurus.</i>	<i>Cynodraco.</i>
<i>Lycosaurus.</i>	<i>Cynosuchus</i> (?).

South African forms :

Cynodontia.**Cynognathus*.*Galesaurus*.*Tigrisuchus*.*Cynochampsia*.*Nythosaurus*.*Scaloposaurus*.

There is little doubt that a considerable synonymy exists among the American forms. A majority of the genera were described from characters of the vertebræ alone and were founded on isolated vertebræ or on small series from separate regions of the spinal column. Thus *Lysorhophus* was founded on the fact that the neural arch is separate from the centrum, and that the capitular articulation of the rib is confined to the preceding intercentrum. In *Theropleura* the neural arch was free from the centrum and the capitulum of the rib was attached to the anterior end of the centrum. In *Dimetrodon* the "capitulum extended downwards and forwards to the anterior end of the centrum, but (as far as observed) there is no facet." In *Embolophorous* the capitulum of the rib is definitely described as joining the preceding intercentrum. As has been shown in the description of the skeleton of *Dimetrodon*, all of the conditions of the capitular articulation described in these genera are found in different parts of the column of the single specimen. The freedom or attachment of the neural arch within the group is hardly more than a character of age. *Metarmosaurus* was founded on the shortness of the centrum and the absence of the capitular face, exactly the conditions that are found in the posterior lumbar and the anterior caudals of *Dimetrodon*. There is little doubt that many of these genera are well founded, but only the consideration of a large amount of material will make it possible to clear up the synonymy.

The position of *Theropleura* is doubtful from the fact that the teeth are said to be the largest in the middle of the molar series, a character that is not common in the *Pelycosauria*, and is quite common in the American forms of the *Pareiasauria*. The same thing is true of the Russian form *Deuterosaurus*.

In our preliminary paper²⁸ the affinities of the *Pelycosauria* were discussed, as follows :

"There cannot be any doubt that *Dimetrodon* is nearest to the *Rhynchocephalia* and *Proganosauria* (*Palæohatteriidae*). The structure of the skull, the vertebral column, and the humerus are of the same type. The presence of a distinct squamosal and prosquamosal is of special interest. The same condition we find in *Sapheosaurus* H. v. Meyer (*Sauranodon* Jourdan) of the Jurassic *Sapheosauridae*; and there is very little doubt that these two elements are also present in *Palæohatteria* Credner. The bone marked squa-

*The group *Cynodontia* was considered by Seeley as worthy of separation from the remainder of the forms by the development of lateral tubercles on the teeth. To this character may be added the union of the superior and the inferior temporal arches, and the more or less complete obliteration of the superior temporal foramen. The *Cynodontia* are so close to the other forms of the group that it is impossible to separate them off even as a sub-order, but they certainly do demand recognition for the advance in the development of the teeth and of the condition of the cranial arches toward the type of the *Gomphodontia*.

mosal by Credner is the prosquamosal; the true squamosal must have been free, and connected with the parietal processes.

"In *Sphænodon* the maxillary forms the lower boundary of the orbit; in *Palæohatteria* and *Dimetrodon*, the jugal excludes the maxillary from the orbit. The vertebræ with the well-developed intercentra, the ribs with the double articulations, can only be compared with those of the *Rhynchocephalia* and *Proganosauria* (*Palæohatteriidae*). The presence of a free central bone in the tarsus of the *Pelycosauria* is an original character, which is shared only by the *Palæohatteriidae* and *Proterosauridae*; but in the *Palæohatteriidae* tarsals 4 and 5 are free, in *Proterosaurus* and *Dimetrodon* they are united, to support metatarsal 4 and metatarsal 5. The humerus of *Dimetrodon* can be directly reduced to that of *Sphænodon*. The entepicondylar foramen is well developed in both; the ectepicondylar foramen of *Sphænodon* is represented by a very distinct ectepicondylar groove in *Dimetrodon*.

"The specialization of the *Pelycosauria* consists in the enormous development of the neural spines of the dorsal vertebræ, and in the reduction of the upper part of the quadrate and its nearly complete inclosure by the squamosal, prosquamosal and quadratojugal. It is quite evident, that the *Pelycosauria* with the two temporal arches and the specialized neural spines cannot be the ancestors of Mammals; they represent a specialized side branch of a line leading from the *Proganosauria* to the *Rhynchocephalia*, which becomes extinct in the Permian.

"The Mammals have a single temporal (zygomatic) arch; the posterior nares are placed far behind, and are roofed over by the maxillary and pterygoid plates; the quadrate is completely co-ossified with the squamosal and quadratojugal; the occipital condyle is double, the entepicondylar foramen is present in all the generalized forms. The ancestors of Mammals must show the same condition.

"Seeley⁴⁵ has combined a number of Permo-triassic *Reptilia* from South Africa into an order which he calls *Gomphodontia*. These Reptiles are: *Tritylodon* Owen (always so far considered a Mammal), *Diademodon* Seeley, *Gomphognathus* Seeley, *Microgomphodon* Seeley, and *Trirachodon* Seeley.

"In *Gomphognathus* we have a double occipital condyle; the posterior nares are placed far behind and are roofed over by the maxillary and pterygoid plates, and there is an entepicondylar foramen. The quadrate seems to be of the reduced form; a condition we see also in the closely related *Cynognathus*.

"These forms look very much like Mammals and could possibly be ancestral to them. We must suppose that the condition of the palate we see in the *Mammalia* and *Gomphodontia*, has been developed from a type we find among the *Rhynchocephalia*. The *Crocodylia*, where we have a similar palate as in Mammals, show us, how such a type

of palate was developed from the *Rhynchocephalia*, through the Belodonts and the Teleosaurs. It is possible, that the *Gomphodontia* originated from the *Proganosauria*. The question to be solved now is: What is the single temporal arch in the *Gomphodontia* and *Mammalia*? There are two possibilities; it represents either both the upper and lower arches united, or the lower one alone, the upper one being reduced.

"Seeley,⁶⁷ in his paper on the *Cynodontia*, gives a lateral view of the skull of *Cynognathus crateronotus*. There is a large supratemporal fossa, but besides, there is a small vacuity, between the squamosal and the jugal. If this vacuity is natural, it can only represent the infratemporal fossa. By the disappearance of this infratemporal fossa a single temporal bar would result. Further researches have to decide this very important question."

In a paper by the junior author⁶⁶ an attempt has been made to show that the vacuity here mentioned in the temporal region of *Cynognathus* is not a fracture, but the final stage in the final union of the two arches to form the zygoma of the mammals.

"A specimen of *Cynognathus crateronotus*, figured by Seeley, shows an opening between the upper and lower arches which was uncertain in origin, there being some reason to suppose it to be the result of an injury to the specimen, but a study of the figure of *Procolophon*, given by Seeley, shows the same condition. The enormous quadratojugal (called squamosal by Leydekker) joins the jugal in front, which in turn joins a slender element by its anterior superior corner; this element runs backwards, forming the lower and back portion of the orbit, and is undoubtedly the postorbital. Behind this element is another bone, the squamosal, or squamosal + prosquamosal, which rests upon the quadratojugal below; between all these elements is a small cavity, exactly as in *Cynognathus*. It is hardly probable that a break would occur in the same place in the two specimens, and so they are considered as showing the final stages of the union of the two arches to form the mammalian zygoma."

If these conclusions be correct there is an uninterrupted chain of forms from the most primitive of the *Pelycosauria* with two widely separated arches to the *Gomphodontia* with a single arch made up of the union of the two and in all probability to the Mammals also. With this progress in the development of the zygomatic arch goes a series of changes in other regions of the skull as the gradual assumption of the tuberculate forms of the teeth and the reduction of the quadrate bone.

The *Pelycosauria* now assumes a most important position in the mammalian-reptilian phylum. As stated in the paper last mentioned,⁶⁶ the group seems to be the beginning of the long line of forms that culminated in the Mammals.

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⁶⁶ Case, E. C. The Significance of Certain Changes in the Temporal Region of the Primitive Reptilia. Am. Nat., Vol. XXXII, pp. 69-74, February, 1898.

⁶⁷ Seeley, H. G. Researches, etc. Part IX, Section 5. On the Skeleton in New Cynodontia from the Karroo Rocks. Phil. Trans. Roy. Soc. London, Vol. CLXXXVI, pp. 59-184, 1895.

⁶⁸ Siebenrock, F. Zur Osteologie des Hatteria-Kopfes. Sitzb. der K. Akad. Wiss. Wien. Bd. CII, Abth. I, June, 1893.

⁶⁹ Cope, E. D. On the Structure of the Brain and Auditory Apparatus of a Theromorphous Reptile of the Permian Epoch. Proc. Am. Phil. Soc., Vol. XXIII, 1885.

⁷⁰ Boule, Marcellin and Glengeaud, Philippe. Le Callibrachion Gaudryi. Bull. de la Société D'Histoire Naturelle D'Autun. T. 16, 1893, pp. 17, 1 pl., 5 figs.

EXPLANATION OF THE PLATES.

Plate I—Dimetrodon incisivus Cope.All figures $\frac{1}{2}$ natural size.

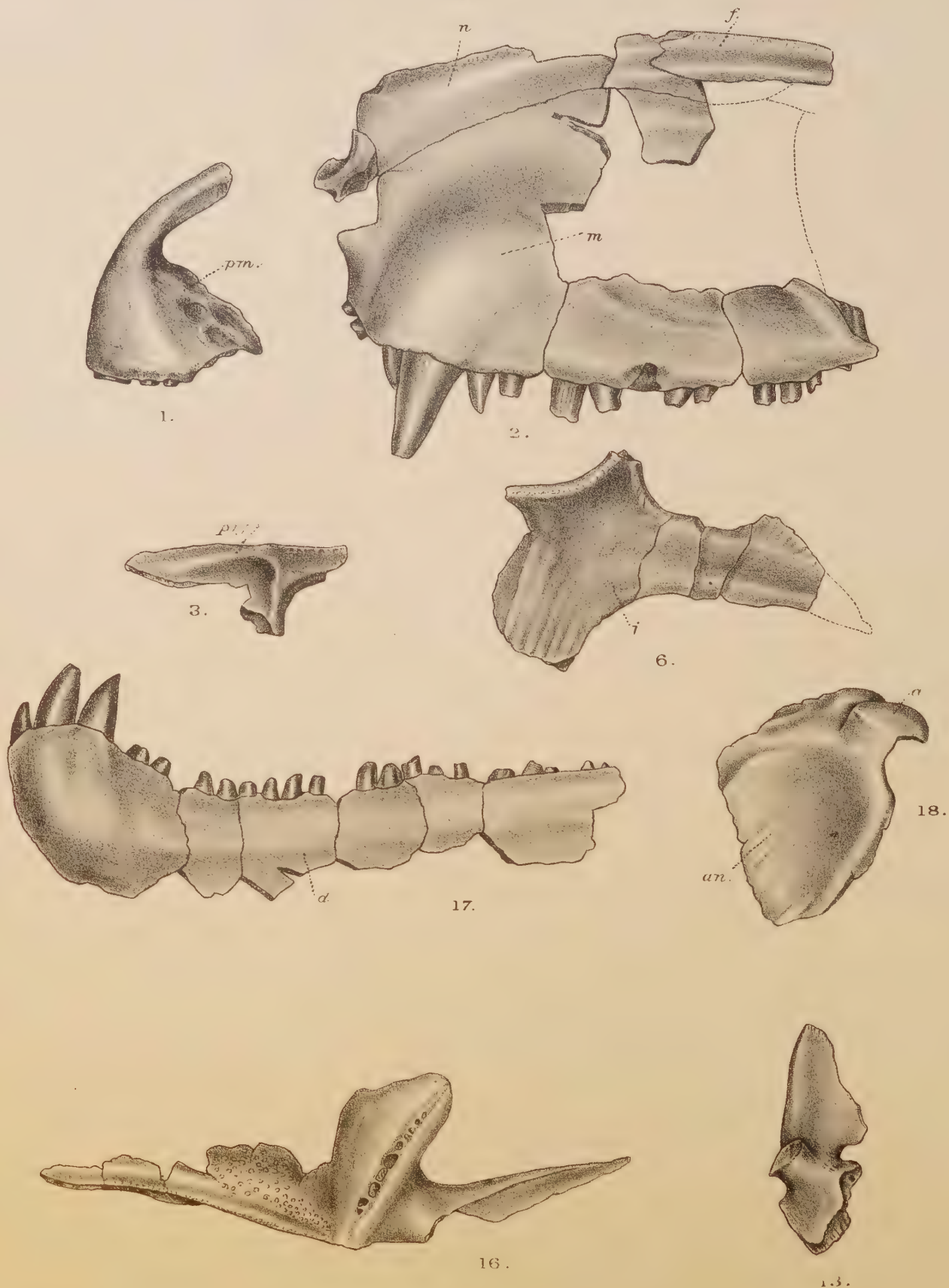
- Fig. 1. Premaxillary = pm.
 Fig. 2. Nasal and maxillary = n. and m.
 Fig. 3. Prefrontal = prf.
 Fig. 4. Frontal = f.
 Fig. 5. Parietal = p.
 Fig. 6. Jugal = j.
 Fig. 7. Postorbital = po.
- | | | | |
|----------|---------------------------|---|--|
| Fig. 8. | } Suspensorial
region. | { | Upper view, quadrate = q.; quadratojugal = qj. |
| Fig. 9. | | | Outer view, squamosal = sq.; prosquamosal = psq. |
| Fig. 10. | | | Lower view. |
- Fig. 11. Cranial region; upper view.
 Fig. 12. Cranial region; lower view.
 Fig. 13. Basisphenoid; lateral view.
 Fig. 14. Basisphenoid; lower view.
 Fig. 15. Pterygoid; external view.
 Fig. 16. Pterygoid; lower view.
 Fig. 17. Dentary = d.
 Fig. 18. Articular region; articular = a.; angular portion of articular = an.

Plate II—Dimetrodon incisivus Cope.

- Fig. 19. First intercentrum.
 a, lower; b, posterior view. $\frac{1}{2}$.
 Fig. 20. Centrum of atlas, second intercentrum and axis. $\frac{1}{2}$.
 Fig. 21. Seventh cervical; lateral view. $\frac{1}{2}$.
 Fig. 22. Seventh cervical; anterior view. $\frac{1}{2}$.
 Fig. 23. Sixth dorsal; anterior view. $\frac{1}{2}$.
 Fig. 24. Sixth dorsal; lateral view. $\frac{1}{2}$.
 Fig. 25. Tenth dorsal; lateral view. $\frac{1}{2}$.
 Fig. 26. Tenth dorsal; anterior view. $\frac{1}{2}$.
 Fig. 27. Three anterior caudals; lateral view. $\frac{1}{2}$.
 Fig. 28. An anterior caudal; anterior view. $\frac{1}{2}$.
 Fig. 29. The same; lower view. $\frac{1}{2}$.

Plate III—Dimetrodon incisivus Cope.

- Fig. 30. Coracoid and scapula ; left side. $\frac{1}{2}$.
Fig. 31. Coracoid and scapula of *Sphenodon* ; left side. 1.
Fig. 32. Humerus, left side ; anterior view. $\frac{1}{2}$.
Fig. 33. Radius, left side ; anterior view. $\frac{1}{2}$.
Fig. 34. Ulna, left side ; anterior view. $\frac{1}{2}$.
Fig. 35. Ulna, left side ; lateral view. $\frac{1}{2}$.
Fig. 36. Femur, right side ; anterior view. $\frac{1}{2}$.
Fig. 37. Femur, right side ; posterior view. $\frac{1}{2}$.
Fig. 38. Tibia, right side ; anterior view. $\frac{1}{2}$.
Fig. 39. Tibia, right side ; lateral view. $\frac{1}{2}$.
Fig. 40. Ninth dorsal vertebra, complete ; posterior view. $\frac{1}{3}$.

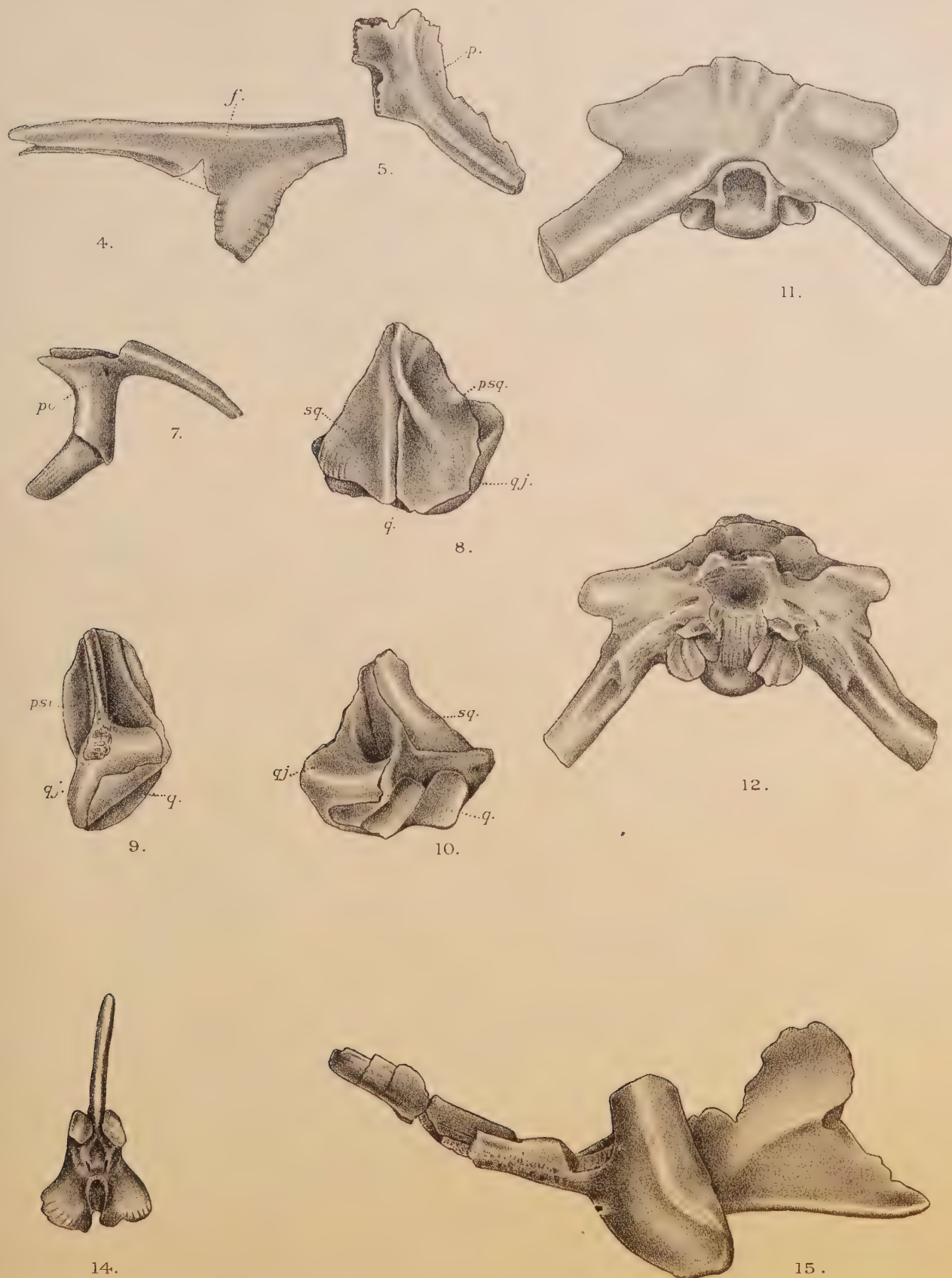


Case del.

1. PREMAXILLARY.
2. NASAL AND MAXILLARY.
3. PREFRONTAL.

6. JUGAL.
13. BASESPHENOID, LATERAL VIEW.
16. PTERYGOID, LOWER VIEW.

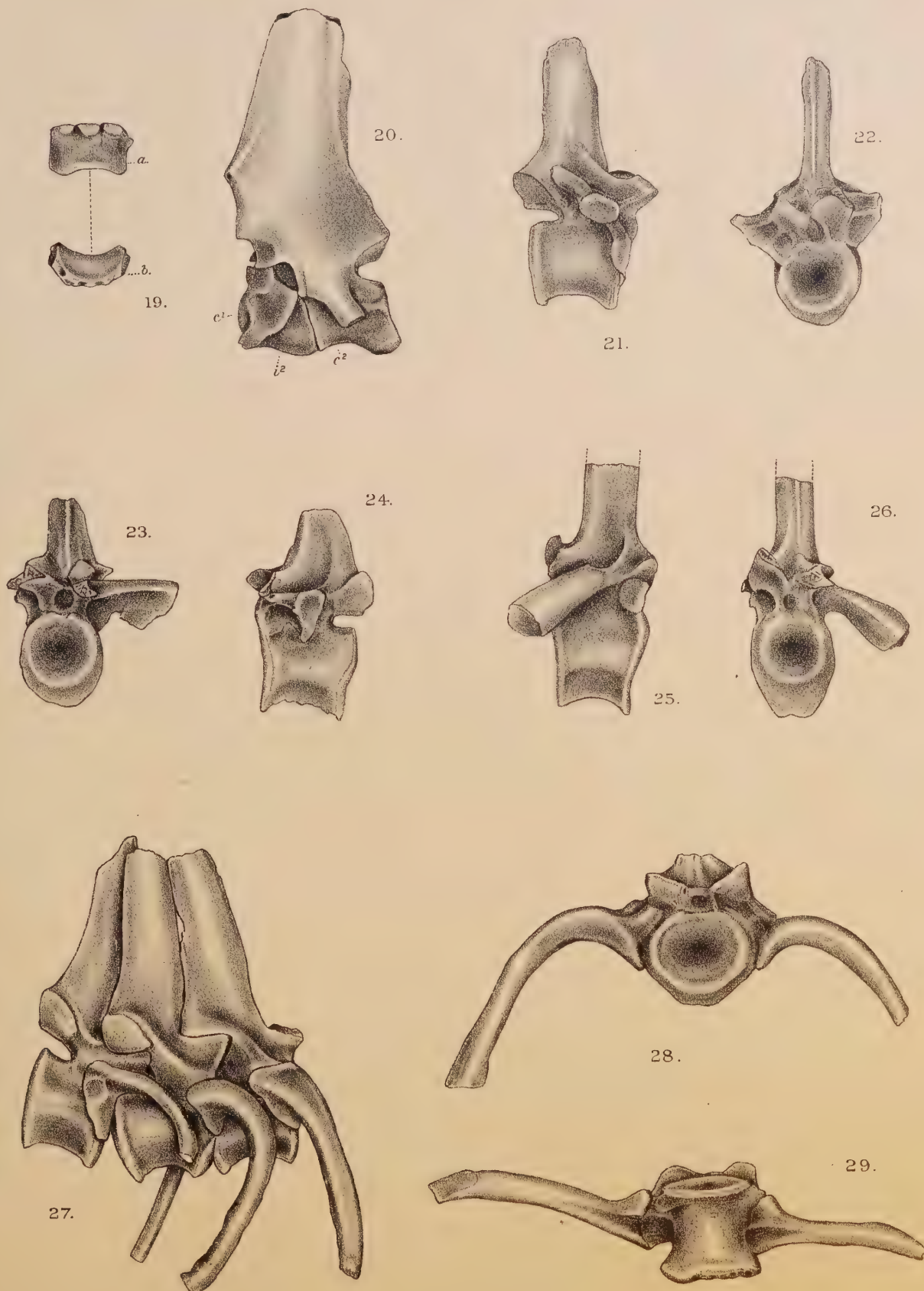
17. DENTARY.
18. ARTICULAR REGION, = A; ARTICULAR.



4. FRONTAL.
5. PARIETAL.
7. POSTORBITAL.

8. {
9. { SUSPENSORIAL REGION
10. {
UPPER VIEW, QUADRATE = Q QUADRATE JUGAL = QJ.
OUTER VIEW, SQUAMOSAL = S, PROSQUAMOSAL PSQ.
LOWER VIEW.

11. CRANIAL REGION, UPPER VIEW.
12. CRANIAL REGION, LOWER VIEW.
14. BASISPHEOID, LOWER VIEW.
15. PTERYGOIND, OUTER VIEW.

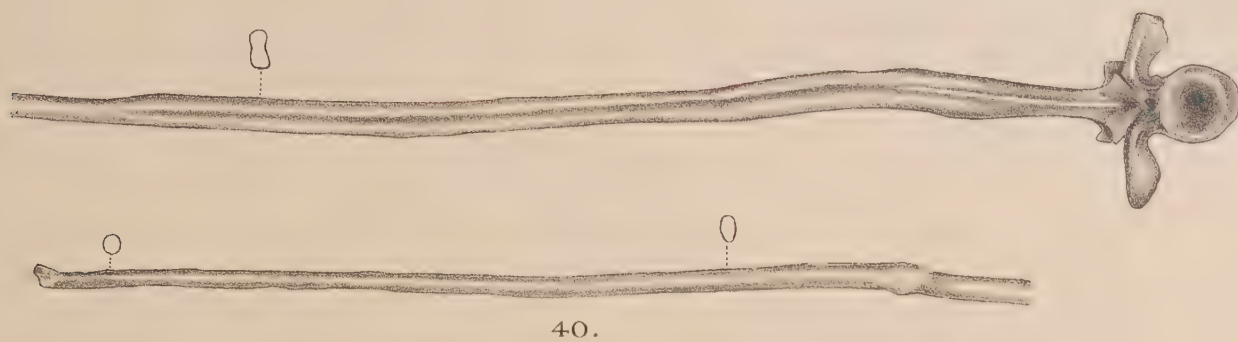


Case, del.

19. FIRST INTERCENTRUM.
20. CENTRUM ATLAS, SECOND INTERCENTRUM AND AXIS.
21. SEVENTH CERVICAL, LATERAL VIEW.
22. SEVENTH CERVICAL, ANTERIOR VIEW.

23. SIXTH DORSAL, ANTERIOR VIEW.
24. SIXTH DORSAL, LATERAL VIEW.
25. TENTH DORSAL, LATERAL VIEW.
26. TENTH DORSAL, ANTERIOR VIEW.

27. THREE ANTERIOR CAUDALS.
28. AN ANTERIOR CAUDAL, ANTERIOR VIEW.
29. THE SAME, LOWER VIEW.



40.



37.



36.



34.



35.

ARTICLE II.

THE CHRONOLOGICAL DISTRIBUTION OF THE ELASMOBRANCHS.

BY O. P. HAY.

Read October 19, 1900.

In *Science*, Vol. x, 1899, p. 683, the writer published a diagram which was designed to represent graphically the chronological distribution of the fossil fishes of North America. Since then it has appeared that a further analysis of the subject is desirable; and this, so far as it pertains to the Elasmobranchii, is here attempted. In the former presentation the Permian period was not separated from that of the Coal-measures; nor were the Mesozoic and Cenozoic ages resolved into their constituent periods. This is here done in a new diagram. Furthermore, the distribution of the fossil Elasmobranchs of Europe is displayed, as well as that of those of North America, the distribution of the former by means of the continuous, that of the latter by the beaded line. From the estimates and statements here given the "ichthyodorulites" have been excluded, although on account of *Onchus* the lines have been made to begin with the Upper Silurian. The numbers accompanying the lines show the number of species known to exist at the times indicated. It may be explained further that the upright lines, and not the spaces, represent the periods of time. For the data appertaining to the European genera and species discussed in this paper, I am indebted especially to Mr. A. S. Woodward's *Catalogue of the Fossil Fishes*; and this work has also furnished me assistance on the American forms.

An examination of the diagram shows that during the Palæozoic era North America possessed a greater number of species than did Europe; while, ever since the Permian period, Europe has considerably surpassed North America. In both North America and Europe the culmination of the class was attained during the Subcarboniferous period; in both there was a rapid decline in genera and species during the time of the Coal-measures. This, as regards America, was shown in the earlier published diagram, but the latter obscured one fact which is here strongly brought out, namely, the

apparently almost complete extinction of the Elasmobranchs during the Permian period. Only about ten species have, so far, been reported from North America, and it is possible that there were even fewer, since the reference of certain deposits in Eastern Illinois to the Permian is perhaps questionable. In Europe about twenty species have been described, the majority of them by Fritsch, within recent years.

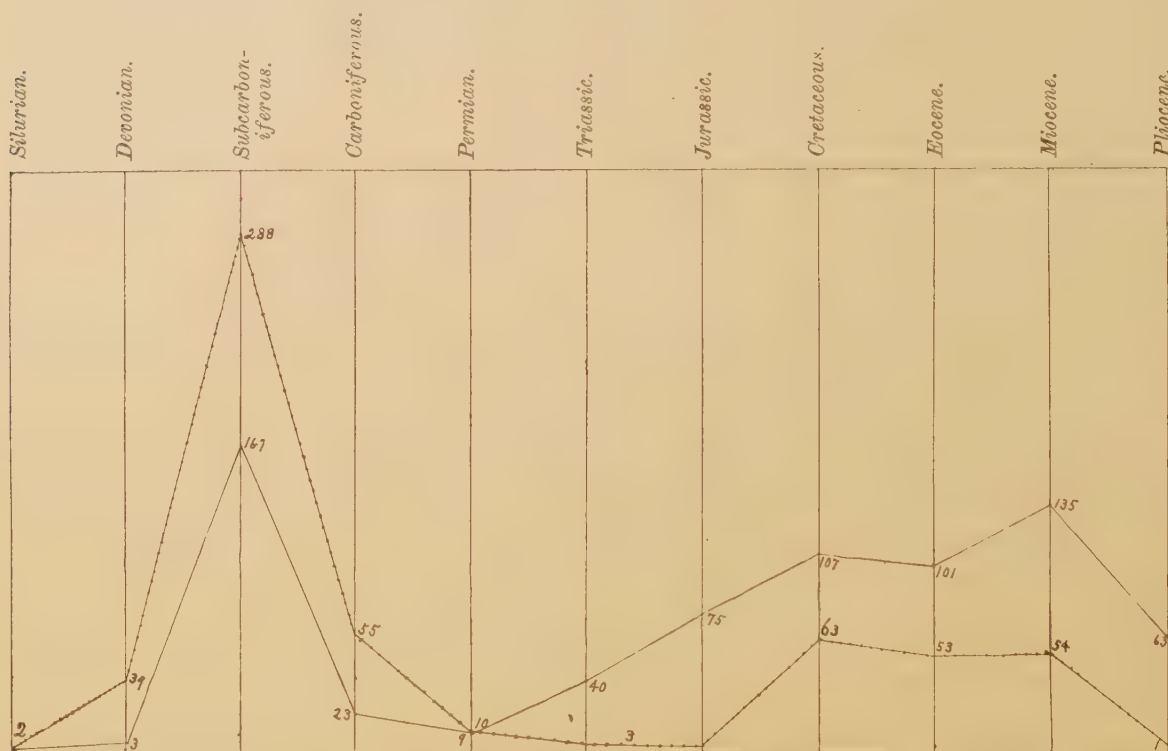


Diagram illustrating distribution of fossil Elasmobranchs.

It is further seen from the diagram that at once after the beginning of the Triassic period the number of species of Elasmobranchs rose rapidly in Europe, while in North America the number apparently even diminished; since only about three species are known to have existed during the time of the laying down of the Jura-Trias. Doubtless this apparent dearth of species is, partly at least, due to the scant development of Triassic and Jurassic rocks in our country.

It might be supposed that in both North America and Europe the conditions during the Permian had been unfavorable for the existence of the genera and species of Elasmobranchs which had flourished in such numbers during the Subcarboniferous; that accordingly they had been driven to some other quarter of the globe; and that it would be found that in some of the Mesozoic periods they had returned to the shores occupied by their Palæozoic ancestors. On this point two things are to be noted: First, we get little or no light on the problem from Permian and early Triassic deposits in other

regions; second, we can hardly expect that the same species would return after the lapse of so long a period. As a matter of fact, no species that existed during the Palæozoic is known from any post-palæozoic formation.

In order to illustrate more clearly the chronological distribution of the Elasmobranchs of the world, I have prepared the accompanying table, which shows the genera that existed during each geological period. As in the case of the diagram, the ichthyodorulites have been excluded; likewise a few unimportant genera, mostly such as existed during only a single period, and most of them belonging to the Subcarboniferous. The genera are arranged under their family names, without reference to their special relationships to one another. The name of every genus which occurs in more than one period is repeated in the proper column. If it is not found in the period following that of its origin, but is found in a still later period, its absence in the intermediate period is indicated by printer's "leaders." All of the genera of the Pliocene column still exist; as do also those there indicated by leaders. Furthermore, two or more genera whose names occur in the same horizontal line have no special relationship to one another; that is, it is not here meant that they stand in the relationship of ancestor and descendant.

In viewing this table we are, first of all perhaps, struck with the blankness of the Triassic column, only four genera there appearing; and these furnished the forty species which existed in the Triassic waters of Europe. The Permian period is somewhat better supplied with genera, although these included only about half as many species as did the three genera of the Triassic. However, the teeth named *Dittodus* quite certainly belong to other genera of Pleuracanthidæ. Hence, we see that not more than from ten to fifteen genera of Elasmobranchs are known to have existed during the Permian period, a meagre number in comparison with the numerous genera of the Subcarboniferous.

Again, examination of the table shows that, with the exception of *Hybodus*, no genus which existed during the Palæozoic era continued on into the post-palæozoic times. The status of *Hybodus* as a Palæozoic genus is open to some doubt and will be considered later. We see, therefore, that whether the Elasmobranchs which had flourished to such an extent during the Subcarboniferous period had remained around the shores of the northern hemisphere during Permian times, but for some reason left only scanty remains; or whether they had been driven to other regions of the globe and returned during post-palæozoic times; when we find them again, if it is their descendants which we find, they have meantime become transformed both specifically and generically.

Table Showing Distribution of the Genera of Fossil Elasmobranchs.

<i>Devonian.</i>	<i>Subcarbon.</i>	<i>Coal-meas.</i>	<i>Permian.</i>	<i>Triassic.</i>	<i>Jurassic.</i>	<i>Cretaceous.</i>	<i>Eocene.</i>	<i>Miocene.</i>	<i>Pliocene.</i>
<i>Pleuracanth-</i> [<i>thidæ</i>]									
Dittodus ¹	Dittodus	Dittodus	Dittodus						
Protodus	Pleuracanthus	Pleuracanthus	Pleuracanthus						
Doliodus	Chondrenche-	Orthacanthus	Orthacanthus						
	[<i>lys</i>]	Diacranodus	Diacranodus						
	Thrinacodus	Compsacan-	Xenacanthus						
		[<i>thus</i>]							
<i>Cladodontidæ</i>									
Cladodus	Cladodus	Cladodus							
Phœbodus	Phœbodus	Symorium							
Monoclado-	Hybocladodus	Styptobasis	Phœbodus*						
[<i>dus</i>]	Lambdodus		Styptobasis						
	Carcharopsis ²								
<i>Cladosela-</i> [<i>chidæ</i>]									
Cladoselache	Cladoselache								
<i>Acanthoës-</i> [<i>sidæ</i>]									
Acanthoëssus ³	Acanthoëssus	Acanthoëssus	Acanthoëssus						
Cheiracanthus		Acanthodopsis							
Ischnacanthus			Traquaria						
Diplacanthus									
Climatius									
Parexus									
	<i>Petalodontidæ</i>								
	Petalodus	Petalodus							
	Chomatodus	Chomatodus							
	Tanaodus	Tanaodus							
	Polyrhizodus	Polyrhizodus							
	Peltodus	Peltodus							
	Ctenoptychius	Ctenoptychius							
	Callopristodus	Callopristodus							
	Ctenopetalus	Ctenopetalus							
	Janassa	Janassa	Janassa						
	Antliodus	Climaxodus	Thoracodus						
	Petalorhyn-	Cymatodus							
	[<i>chus</i>]								
	Fissodus	Calopodus							
	Lisgodus	Lisgodus							
<i>Psammodon-</i> [<i>tidæ</i>]									
Psammodus	Psammodus	Psammodus							
	Copodus								
	Archæobatis								
	<i>Cochliodon-</i> [<i>tidæ</i>]								
Helodus*	Helodus	Helodus							
	Pleuroplax	Pleuroplax							
	Sandalodus	Sandalodus							
	Platyxystro-	Platyxystro-							
	[<i>dus</i> ⁴]	[<i>dus</i>]							
	Deltodus	Deltodus							
	Pœcilodus	Pœcilodus							
	Vaticinodus	Vaticinodus							
	Orthopleuro-	Orthopleuro-							
	[<i>dus</i>]	[<i>dus</i>]							
	Cochliodus								
Xenodus ⁵	Venustodus								
	Deltodopsis								
	Psephodus								
	Streblodus								
	Icanodus ⁶								
	Lophodus								

[illegible]

Devonian.	Subcarbon.	Coal-meas.	Permian.	Triassic.	Jurassic.	Cretaceous.	Eocene.	Miocene.	Pliocene.
						<i>Rajidae</i> Raja Cyclobatis	Raja Platyrrhina	Raja Acanthobatis	Raja Oncobatis
							<i>Narcobatidae</i> Narcobatus ¹⁸ Narcine		
						<i>Pristidae</i> Sclerorhynchus Amblypristis Propristis	Pristis	Pristis	
						<i>Dasyatidae</i> Dasyatis ¹⁹ ?	Dasyatis Urolophus Xyphotrygon Tæniura	Dasyatis	Dasyatis
					<i>Myliobatidae</i> Myliobatis?	Myliobatis? Rhinoptera? Aëtobatis? Rhombodus	Myliobatis Rhinoptera Aëtobatis Promyliobatis	Myliobatis Rhinoptera Aëtobatis	Myliobatis Rhinoptera Aëtobatis
						<i>Ptychodontidae</i> Ptychodus Hemiptychodus			
<i>Ptyctodontidae</i> Ptyctodus Rhynchodus Palæomyxus			Chalcodus?		<i>Squalorajidae</i> Squaloraja				
					<i>Myriacanthidae</i> Myriacanthus Chimærops				
					<i>Chimæridae</i> Ganodus Ischyodus	Edaphodon Ischyodus Elasmodus Leptomylus Elasmodectes Bryactinus Sphagepœa Isotænia	Edaphodon Mylognathus Elasmodus	Edaphodon? Chimæra?	Chimæra

¹ Diplodus Ag.; type of Dittodus Owen to be *D. divergens* Owen = *Diplodus gibbosus* Ag.

² Dicrenodus Rom.

³ Acanthodes.

⁴ Xystrodus Ag.

⁵ Goniodus Newb.

⁶ Tomodus Davis.

⁷ Stenmatodus St. J. & W.

⁸ Cestracion Cuv.

⁹ Notidanus Cuv.

¹⁰ Orthacodus A. S. W.

¹¹ Odontaspis Ag.

¹² Oxyrhina Ag.

¹³ Scyllium Cuv.

¹⁴ Carcharias Raf.

¹⁵ Galeus Cuv.

¹⁶ Scymnus Cuv.

¹⁷ Spinax Cuv.

¹⁸ Torpedo Dum.

¹⁹ Trygon Cuv.

* On the authority of Dr. C. R. Eastman.

Furthermore, with the exception of the family Heterodontidæ (Cestraciontidæ), as defined by Mr. Woodward, no family of Elasmobranchs crosses the line dividing the Palæozoic from the post-palæozoic world.

It may be profitable to discuss the fate of the various Palæozoic families of Elasmobranchs, so far as we are able to reach conclusions regarding them from the materials at our command. The Pleuracanthidæ and the Cladodontidæ are so different from all other known sharks that they have been made to constitute a distinct order, the Ichthyotomi. This order represents a distinct offshoot, which extends back as far at least as the Devonian. The Pleuracanthidæ had their maximum of development in species in the Coal-measures; the Cladodontidæ during the Subcarboniferous. In the States lying along the Mississippi river we find the species of the genus *Cladodus* pretty evenly distributed throughout the various divisions of the Subcarboniferous rocks, about thirty-two species occurring therein to seven in the whole thickness of the Coal-measures of the same region. The upper division of the Subcarboniferous, the Chester, alone contained five species. This shows that the genus was a declining one during the period of the Coal-measures. The other genera of the family which existed during the Subcarboniferous period failed to reach the period of the Coal-measures. The structure of the Pleuracanthidæ is quite well understood; that of the Cladodontidæ much less satisfactorily; but from what we do know of the structure and history of the two families, it is very improbable that they were the ancestors of any known sharks of the post-palæozoic world.

The Cladoselachidæ is a small family of a single genus and a very few species. They are, with respect to their paired fins, very generalized; with respect to their tails at least, they are highly specialized. They are not known to pass beyond the early Subcarboniferous;* and no related forms are recognized thereafter.

We have no evidences that the Acanthodii possessed any representatives after the Permian period. The order had its maximum of development in the Devonian. The typical genus, *Acanthoëssus*, continued on into the Permian, in which Fritsch has recently discovered one or two additional genera, containing two species. The members of the order differ so much from other Elasmobranchs that their relationships with the sharks have been doubted. They almost certainly left no post-palæozoic descendants.

Of the numerous genera of the Petalodontidæ the only genus that continued on into the Permian is *Janassa*. Here it is associated with Cope's *Thoracodus*. Hasse has suggested that *Janassa* has relationships with our modern rays; but Jaekel, who has studied this genus, concludes that it had nothing to do with the rays. The Petalodontidæ were, after the time of the Subcarboniferous, a declining group. During this period there

* Dean, B., 1894, *Trans. N. Y. Acad. Sci.*, xiii, p. 115.

were in existence about ninety species; during the Coal-measures, fifteen; during the Permian, only five. Thereafter they are not known.

The Cochliodontidæ formed an extensive family, with a dentition which reminds one strongly of that of the modern *Heterodontus* (Cestracion); but this dentition was, in a way, highly specialized; and it is quite improbable that it later became simplified into the dentition of any post-palæozoic sharks. Moreover, this family too was a decadent one after Subcarboniferous times; since out of more than one hundred and seventy-five species which have been described, only fifteen or fewer belong to the Coal-measures. In the Mississippi valley the family had its culmination in the Keokuk and St. Louis epochs, the middle of the Subcarboniferous. The whole thickness of the deposits of the Coal-measures of the Mississippi valley has furnished only about ten species, about as many as are found in the Kinderhook, a formation about two hundred feet thick. It may be further observed that not a single known genus of this family came into existence during the Coal-measures period.

This review of families brings us to a group of genera which have been included by Mr. A. S. Woodward in the family Cestraciontidæ, or as the writer prefers to call it, Heterodontidæ. This family may, for convenience of discussion, be regarded as consisting of a group of Palæozoic, or more specifically Carboniferous, genera and of a group of post-palæozoic genera. The former group, like most of the families which we have so far considered, had its maximum of development, both as to genera and species, during the Subcarboniferous. Nearly all the genera too had their origin during Subcarboniferous times. Of this group *Orodus* may be taken as the type, being the best known, most abundant in species and most widely distributed. As in the case of the other genera of this group, all we know about *Orodus* is derived from its teeth; and these generally occur isolated. It is admitted by authors that these teeth are not greatly different from those of *Hybodus* of post-palæozoic times. As defined and accepted, however, *Orodus* belongs essentially to the Subcarboniferous period. Of thirty-eight described species only one belongs to the Coal-measures, and this to the lower division. Of nineteen species described from the rocks along the Mississippi river one belongs to the lower Coal-measures, one to the Chester, the uppermost division of the Subcarboniferous; the remainder are nearly equally distributed among the other divisions. In Great Britain the maximum of development of *Orodus* is in the lower portion of the Subcarboniferous. *Campodus* has five species in the Coal-measures, two in the Subcarboniferous. Of the five species of *Sphenacanthus* two belong to the Subcarboniferous, three to the lower Coal-measures. On the whole, the Palæozoic contingent of the Heterodontidæ was a declining one from the time of the Subcarboniferous period.

The other members of Mr. Woodward's Cestraciontidæ are found principally in the

post-palæozoic deposits, and attained the height of their development during the Jurassic; although the two principal genera, *Hybodus* and *Acrodus*, had their maximum in the Triassic. It is not beyond possibility that *Hybodus* occurs in the Permian, a few teeth from that formation having been assigned to the genus. It has indeed been carried back by some palæontologists to the Coal-measures, and into the Subcarboniferous; but this would give to *Hybodus* a term of existence equaled by no other vertebrate genus, and a term quite improbable. Furthermore, no other genus, either Elasmobranchian or of true fishes, is known with certainty to have passed from the Palæozoic to Mesozoic times. If *Hybodus* has done this it holds a unique position. A similar remark may be made regarding the family Heterodontidæ, as limited by Mr. Woodward. If the Carboniferous genera are included in it, the family has come down to our day from the beginning of the Subcarboniferous period; and Rohon describes *Rhabdiodus*, said to be a Hybodontid, from the Upper Silurian. No other family of fishes can claim such a history. We would have to go to the invertebrates to find a family that has existed so long. The assignment of the Palæozoic genera to the family is based wholly on similarities in the teeth; and this character is confessedly unreliable in sharks living in far removed periods of time. Within a few years we have had it announced that in *Chlamydoselache* a living genus of Cladodonts had been discovered; but the error was soon dispelled. Authors differ much in their disposition of the genera here concerned. Dr. Zittel recognizes a family Hybodontidæ in which are put *Hybodus*, *Cladodus* and a number of Subcarboniferous genera; while *Orodus*, *Campodus*, *Acrodus*, etc., are put in the Cestraciontidæ. Jaekel would exclude from the latter family *Orodus*, *Campodus*, etc. Therefore, I do not believe that we shall lose anything by retaining at least the genera of the Carboniferous age in a family with a distinct name, Orodontidæ; and this I have done in the table of genera. Some day a fortunate discovery of some member of the group will reveal its relationships to modern forms. And I believe that I do not err in saying that the discoveries hitherto made of the skeletons of Palæozoic sharks have proved their possessors to have been quite different from modern forms. As proofs of this assertion may be mentioned *Cladodus*, *Cladoselache* and *Pleuracanthus* and its allies.

However, it would be rash to affirm that the post-palæozoic Heterodontidæ have not been derived from some member of the Orodonts. The latter family is apparently the least specialized of the ancient groups, and some one of its less differentiated and more plastic genera may have furnished the progenitors, not only of the Heterodontidæ, but possibly of all the modern families of sharks and rays.

It might be possible, as already suggested, to account for the break in the continuity of the genera and families of Elasmobranchs which occurred during the Permian and earlier Triassic on the ground that the environment along the shores where deposits were

being made was not favorable for their existence; that consequently they migrated elsewhere; and that when they returned, so much time had elapsed that they had necessarily become transformed beyond recognition. We must, however, keep in mind that the Elasmobranchs of the Subcarboniferous period were evidently mostly dwellers in clear open seas, that such seas were probably always accessible to such free-swimming animals, and that the space of time in question has been spanned by more than one family of the higher fishes. The Cœlacanthidæ are known to have survived from the Devonian to the Cretaceous. The Palæoniscidæ likewise began in the Devonian and did not perish until in middle Mesozoic times. During the Subcarboniferous period there existed over forty species. With each succeeding period the number of species became reduced, but the *vis viva* of the family was such that it penetrated into the Jurassic. In the Permian period there existed about thirty known species; in the Trias, fifteen species. None of the genera, however, existed in both Palæozoic and post-palæozoic times.

The Semionotidæ furnish another example of a family which lived through the transition from Palæozoic to later times. It began in the Permian in a feeble way, with a single genus and some five or six species; but the stock possessed such vigor that it was able to endure until in the Cretaceous. In Triassic times there existed a dozen genera and nearly seventy species. The Permian genus *Acentrophorus* is believed to be represented in the Triassic by a single American species; but the identification is in doubt.

It seems probable, therefore, that the failure of the Palæozoic families of Elasmobranchs to perpetuate themselves beyond the Permian period was due more to the organization of the animals themselves than to any specially unfavorable environment. Their vitality seems to have become reduced, and for that reason they perished. This is also indicated by the fact that after the Subcarboniferous period very few new genera were evolved. Among the Palæoniscidæ, on the contrary, new genera were brought into existence with each succeeding period up to near the end of their history. The same is true of the Semionotidæ, although their course was a briefer one. Among the Elasmobranchs themselves, we find that when, after the middle of the Trias, they entered on a new career, the production of new genera went on for a time with energy. Only a few appeared in the Trias, many in the Jurassic, a greater number in the Cretaceous, many in the Eocene. Since then that pristine vigor shown in the organization of new genera has apparently declined; and we may consequently regard the Elasmobranchs of to-day as a moribund race. The seas of the tropical regions are now the homes of the greater number of living forms, and the Tertiary rocks of the tropics have not been thoroughly enough explored to enable us to say how the number of the Miocene species compares with that of the living species; but the Miocene sharks and rays of Europe far outnumber

those now inhabiting European seas. According to Dr. Günther's *Catalogue of the Fishes in the British Museum*, Vol. viii, there are now living only seventy-six European species. During the Miocene there existed one hundred and thirty-five species in that region. In North America the recent species exceed those known from the Miocene in the ratio of eighty-six to fifty-seven; but if only those found along our eastern and southern coasts are compared with the Miocene species of the same region, the numbers are about equal. Doubtless, when our marine Miocene fauna is better known, especially that of our western coast, the number of species will be increased. When all the Miocene species of Europe and America combined are compared with all the living species of the same region, we find the numbers to be approximately 155 and 135. No reason is apparent why these two great regions should not represent well the state of Elasmobranchian development during Miocene times and that of to-day; and even if we leave out of account the insufficiency of the geological record, it shows that, as regards numbers of species, this class has declined.

The remarkable reduction in the number of genera and species of Elasmobranchs during the Permian period finds a parallel in the apparently almost complete extinction of the Brachiopoda at the same time. The facts bearing on this subject have been obtained from Mr. Charles Schuchert's *Synopsis of the Brachiopoda of North America*. The following table shows the number of genera which are known to have existed at each geological age:

Cambrian	28	Triassic	43
Ordovician	66	Jurassic	43
Silurian	75	Cretaceous	31
Devonian	101	Tertiary.....	20
Carboniferous	76		

This table has the appearance of proving that the Brachiopoda culminated during the Devonian age, thereafter began to decline, and have continued to diminish gradually to the end of the Tertiary; but if we inquire a little more closely into their chronological distribution we shall find that in the Permian deposits there have been found only eight genera and eight species, as Schuchert has shown. Therefore, a curve that would represent the history of the Brachiopoda would resemble closely that representing the history of the Elasmobranchs, except that many phases of the former curve would fall about one age earlier than in the case of the latter.

Concerning the other families of post-palæozoic sharks, I have no remarks to make. The group of rays will be briefly considered. The question of their origin assumes importance from the discovery of *Tamiodontis*, described by Dr. C. R. Eastman.* The

* *Amer. Jour. Sci.*, iv, 1897, p. 85.

specimen on which the genus rests is supposed to have been derived from the Devonian rocks of Kentucky, but may have come from the Subcarboniferous. Dr. Eastman regards this fossil as a true ray; and it certainly possesses many resemblances to one.

Morphologically the rays are not greatly different from the sharks. Dr. Jaekel* holds that the essential character of the rays is found in the attachment of the pectoral fin-supports to the side of the head, all other characters having resulted either from this forward extension and anchorage of the fins to the side of the head or from the mode of life affected by the rays. He doubts, however, the unity of the group which includes the rays, Batoidei of writers. He is inclined to hold that the Dasyatidæ (Trygonidæ) and the Myliobatidæ, the two families forming his "Centrobatidæ" (*Masticura*, Gill, 1872), have sprung from forms like *Ptychodus* and *Strophodus*; and in a recent publication,† the line is traced back to the Psephodontidæ and thence to the Holocephali. The other division of the rays, Jaekel's *Rhinoraji* (*Pachyura*, Gill, 1872), are supposed to have originated from the Spinacidæ (Squalidæ). The two groups are thus removed far apart. I believe, however, that we can say that we have no trustworthy record of the *Masticura* before the Cretaceous, when at least *Rhombodus* and the *Ptychodontidæ* lived; nor of the *Pachyura* before the Jurassic, when *Rhinobatis*, the most primitive of the group, first appears to us.

Now, on the page of this history of the rays, so modern in comparison with the great age of the class Elasmobranchii, we are confronted with the proposition that *Tamiodontis* of the Devonian is a true ray. If the divergence of the Batoidei or either division of them occurred so near the root of the Elasmobranchian stem as the Devonian, they ought to be dignified with the rank of superorder or order, instead of being grudgingly given the rank of suborder, as is done by most writers. We must, then, have very satisfactory evidence before we can admit *Tamiodontis* among the Batoidei. I do not believe that it has been produced. The three characters relied on by Dr. Eastman, in his excellent description, to support his views, are the elongated rostrum, the prominent nasal capsules and the antorbital processes, which are supposed to have served to attach the pectoral fins to the head. Now, the rostrum is one of the most variable organs in presence, form and size, not only among the sharks, but also among the rays. In the shark *Centrophorus* it equals in length the rest of the skull; in the Myliobatid rays it is wholly absent. As regards the antorbital cartilages of *Tamiodontis*, there are, it seems to me, sufficient evidences that they did not support the pectoral fins. In the rays these cartilages are articulated to the nasal capsules, and the distal extremity of each is directed backward along the inner side of the fin. In *Tamiodontis* there is no

* *Die Eocänen Selachier Monte Bolca*, 1894, p. 45.

† *Zeitschr. deutsch. Geolog. Gesellsch.*, li, 1898, p. 298.

indication of any articulation, and the cartilages are directed outward and forward. If it is supposed that there was originally an articulation which has become effaced during fossilization, we must make the unlikely assumption that the two cartilages have been removed from their natural, posteriorly directed position and made to take new positions, symmetrical on the two sides.

The size of the nasal capsules furnishes no certain evidence of the batoid nature of this animal. The hammerhead sharks have these larger than any of the rays; and it is not improbable that *Tamiodontis* had its nasal capsules developed for some such function as is subserved by this organ in the modern hammerheads. *Tamiodontis* must have been quite different in many respects from anything now in existence. Dr. Eastman has figured two structures which he has identified as the postorbital arches. He states that each of these appears to be cut off from the rest of the skull by a small cleft; but he says these clefts have every appearance of being fortuitous. These are alike on the two sides, and to me they appear wholly natural and as the indications of articulations. As Dr. Eastman suggests, the portions thus cut off do not appear to be metapterygoids; and we are left in the dark as to their real nature. It appears to me not improbable that the structures outside the clefts are portions of the palatoquadrate arch, attached to the postorbital process, as it is in some modern sharks. At all events it appears that we are hardly justified in concluding that the fossil in question, which lived in the middle of the Palæozoic era, belongs to a group which, so far as we have any reliable evidence, did not come into existence until the Mesozoic era was well advanced.

ARTICLE III.

RESULTS OF OBSERVATION WITH THE ZENITH TELESCOPE OF THE SAYRE OBSERVATORY FROM JANUARY 19, 1894, TO AUGUST 19, 1895.

BY CHARLES L. DOOLITTLE.

Read October 19, 1900.

INTRODUCTION.

The Sayre Observatory, situated at South Bethlehem, Pennsylvania, owes its existence to the liberality of Robert H. Sayre, at whose expense it was erected and equipped in 1868. The object was primarily that of supplying facilities for the instruction of students of the Lehigh University in practical Astronomy. One of the first tasks undertaken by the author of this paper upon taking charge of the department of Astronomy at that institution in 1875 was a very careful determination of the latitude.

The question of possible variations was one of those had in mind at that time. It was then supposed that if anything of this kind took place of sufficient magnitude to be measurable, the changes would be secular in character, and that later determinations might furnish valuable data for deciding the question whether or not such changes existed. This first determination was not finally completed until 1878.

A re-determination was made in 1885-86, which indicated a change of about $0''.4$, though the reality of this change was at that time naturally an object of much skepticism.

The work was resumed in 1888, and was continued with some interruptions until the summer of 1895, when my connection with the Lehigh University terminated. The present paper deals with the results obtained from January 19, 1894, to August 19, 1895. Although this is a continuation of work done during previous years, the methods pursued were such as to make this in so far an independent series that it may very properly be presented separately. Moreover, as a re-discussion of the earlier observations and their publication in full constitutes a part of the general plan, they will call for no further consideration here.

The final preparation of this material for publication has been delayed by the circumstance that a preliminary reduction showed it to be very desirable that the star declinations should be determined with a high degree of accuracy and carefully reduced to a

homogeneous system. As but little material for this purpose existed in the case of a considerable number of the stars employed, a complete re-observation of the entire list was kindly undertaken by R. H. Tucker, of the Lick Observatory, and that of individual stars at other places; finally in the spring of 1899 an appropriation by the trustees of the Gould fund provided for the employment of a computer, so that now what for present purposes may be regarded as the final values of the stellar coördinates are available.

In the present series the plan proposed in 1890 by Dr. F. Küstner* was followed. This consists in the employment of four groups of stars, so arranged that they may be connected by evening observations on one group, accompanied by morning observations on the consecutive one. This furnishes the means of adjusting the results to a homogeneous system, and at the same time, as a kind of by-product, a determination of the constant of aberration independently of variations in the latitude.

In the present case the four groups were distributed as follows:

Group	I	5 ^h 31 ^m	to	7 ^h 23 ^m	10	pairs.
	II	14 1	to	15 51	10	"
	III	17 30	to	19 35	9	"
	IV	21 29	to	23 52	12	"

The interval between I and II proved to be somewhat too great, for, although these groups were observed during the long nights of January, February and March, the excessive proportion of unfavorable weather at this season made it somewhat difficult to obtain the desired number of satisfactory observations.

The Instrument.

This is a Zenith Telescope by E. & G. W. Blunt, of New York. It is said to have been purchased of the United States Coast Survey in 1868, when the Observatory was first erected. It was then in poor condition, and had probably not been in active service for some time. It was at different times overhauled and repaired, and finally, in 1892, provided by G. Saegmüller, of Washington, with two very fine levels. Though not ranking as a first-class modern instrument, it proved capable, with care and attention in its use, of giving results which are believed to be worthy of entire confidence.

The aperture of the telescope is three inches; focal length, forty-one inches. A diagonal eye-piece was employed, magnifying seventy-five diameters.

The Levels.

The two levels above mentioned were designated A and B. Previous experience with levels had shown that in some cases the scale values did not remain constant. Cases of deterioration had also been met with, good tubes in time becoming worthless.

* *Astronomische Nachrichten*, Bd. 126, No. 3015.

It was therefore determined to examine thoroughly these levels at intervals of three months. As no important changes were found, they afterward received less frequent attention, but the process was always repeated at least twice each year.

In this investigation the ordinary level-trier was employed, consisting of a horizontal bar with a micrometer screw at one end. The proportions in the present case were such that one division of the micrometer head corresponded to an angle of 1" in the inclination of the bar.

The level tubes were placed in position, carefully protected from disturbances of all kinds and allowed to remain for an hour or two in order to allow the temperature of all parts of the apparatus to come to a condition of equilibrium. The bubble was then brought near one end of the tube and the scale reading noted. The screw was next moved forward two divisions and the scale again read, and so on through something more than the entire part of the scale actually used in observation.

The screw is now moved backward and the reading of the scale noted at the same screw readings as before. From one to two minutes are allowed for the bubble to come to rest after moving the screw. If too much time elapses there is danger that changes of temperature or other disturbing causes may vitiate the result.

The process is illustrated by the following record of the determination of the value of A :

1894, April 1, 10.30 A.M.	Micrometer.	Bubble.		Mean.	Bubble.		Mean.	Thermometer, 56°.4.
		N.	S.		N.	S.		
Backward.	1	71	3.8	26.1	14.95	3.4	25.5	14.45
	2	69	4.8	27.1	15.95	4.6	26.7	15.65
	3	67	6.3	28.6	17.45	6.2	28.3	17.25
	4	65	8.3	30.6	19.45	7.8	29.9	18.85
	5	63	9.8	32.1	20.95	9.4	31.5	20.45
	6	61	11.3	33.6	22.45	10.9	33.1	22.00
	7	59	13.0	35.3	24.15	12.7	34.9	23.80
	8	57	14.7	37.0	25.85	14.2	36.4	25.30
	9	55	16.4	38.6	27.50	15.9	38.1	27.00
	10	53	18.2	40.5	29.35	17.7	39.9	28.80
	11	51	19.6	41.8	30.70	19.2	41.4	30.30
	12	49	21.0	43.2	32.10	20.5	42.8	31.65
	13	47	22.7	45.0	33.85	22.3	44.5	33.40
	14	45	24.6	46.8	35.70	23.8	46.1	34.95
Forward.	8—1			10.90				10.85
	9—2			11.55				11.35
	10—3			11.90				11.55
	11—4			11.25				11.45
	12—5			11.15				11.20
	13—6			11.40				11.40
	14—7			11.55				11.15
	14''	=		11.386				11.279
	One division	=		1''.229				1''.241

The same values of the levels were not employed throughout the entire latitude series,

but these values were revised from time to time as new material gave promise of improvement.

The values used were as follows :

1894, January 19–April 26,	A 1''.280	B 1''.028
April 30–September 15,	1''.276	1''.008
October 2–December 6,	1''.292	1''.008
1894, December 23–1895, August 19,	1''.284	1''.024

The Reticle.

This is fitted with three vertical threads and one horizontal. The latter is for the purpose of marking the middle of the field, but it is not required for this. Moreover, it involves the inconvenience that, where the difference of zenith distance is small, one component is found on this thread with surprising frequency, thus interfering seriously with its bisection.

In practice, the stars were bisected at the time of passing each vertical thread. The equatorial intervals of the side threads from the middle one were 13°.46 and 13°.61.

The correction to the latitude for the interval τ is

$$\frac{(15\tau)^2}{4} \sin 1'' \tan \delta.$$

This is computed for each pair employed and is practically constant for the entire time embraced by the series.

The Micrometer.

The movable frame carries five threads at intervals of approximately ten revolutions of the screw. There are small pieces of brass near one end of the threads marked with 1, 2, 3, 4 and 5 points respectively, to avoid mistakes in identifying the threads. When the difference of zenith distance is not greater than twenty revolutions, both stars were generally bisected with III; for greater differences II and IV were used to avoid turning the screw through so great a number of revolutions. I and V were not used.

It was necessary to determine carefully the distance between threads II and IV, and as this did not remain constant, the operation must be frequently repeated. After some experimenting, it was found that this could be most satisfactorily done by pointing the telescope toward the sky during daylight and bringing the threads in succession up to the fixed thread before mentioned, moving the screw until the line of light between the two vanished.

In the pages which follow, giving details of the latitude determinations, the column headed δ contains this correction where required, combined with a second correction to the micrometer, the explanation of which will be given presently.

The proper value of the micrometer screw has proved a troublesome question, as it has been found to be a variable quantity. δ Ursæ Minoris and 51 Cephei were observed on twenty-three nights during the progress of the work, one star being taken at eastern elongation, preceded or followed, as the case might be, by the other at western elongation. As the altitude of one would be increasing and that of the other diminishing, the mean result should be practically free from errors due to gradual changes of refraction and others of a like character. A preliminary reduction of the latitude observations showed that no one value of the micrometer screw could harmonize the entire series. Evidently the screw had become worn with long service, and the wearing process was still going on at an appreciable rate. A somewhat roughly determined correction for temperature changes removed a part of the difficulty, but not all.

On July 25, 1894, the micrometer was sent to Stackpole & Brother, of New York, for repairs, including a change in the tension of the springs. This naturally produced a change of value at this point, but it was constant neither before nor after. Finally, the conclusion was reached that the screw value must be deduced from the latitude observations themselves and be treated as a variable quantity.

In order to have this method of procedure worthy of confidence, more precise values of the star places were required than those before employed, hence the final reduction was postponed until these became available.

It was observed that the screw was affected by progressive errors of considerable magnitude. An investigation of this matter had formerly been made by employing a measuring engine designed by Prof. William Harkness, of the United States Naval Observatory; but the results had ceased to be applicable, probably a consequence of the wearing of the screw before referred to. The corrections here used were derived from the above-mentioned transits of δ Ursæ Minoris and 51 Cephei.

Let n be any number of revolutions of the screw reckoned from the middle of the scale, the middle in this case being at the twentieth revolution.

Let R be the mean value of one revolution.

If the errors be uniformly progressive, the space S , corresponding to n , will be of the form:

$$S = Rn + \rho n^2$$

For a second reading:

$$S' = Rn' + \rho n'^2$$

$$S - S' = R(n - n') + \rho(n^2 - n'^2)$$

The transits of the stars in question were always observed for each revolution of the screw from scale readings 33 to 7. The observed times are first corrected for level changes and for curvature of the stars' path. They are then combined by subtracting

33 from 19, 32 from 18, — — — —, 21 from 7, thus obtaining a series of values of the time required by the star to pass over the space measured by fourteen revolutions of the screw. The difference between any value and the mean of all is the observed correction on account of ρ , expressed in seconds of time. This must finally be converted into its equivalent value in terms of revolutions of the screw.

The means of the differences so found are given in the accompanying table, those for 51 Cephei having been reduced to the equivalent in terms of δ Ursæ Minoris:

	<i>Micrometer.</i>	$n^2 - n'^2$	<i>Observed Difference.</i>	<i>v.</i>
			^s	^s
1	19 — 33	— 168	— 3.90	+ .27
2	18 — 32	— 140	— 3.25	+ .22
3	17 — 31	— 112	— 2.55	+ .23
4	16 — 30	— 84	— 2.21	— .13
5	15 — 29	— 56	— 1.48	— .09
6	14 — 28	— 28	— 1.11	— .42
7	13 — 27	0	— .03	— .03
8	12 — 26	+ 28	+ .68	+ .01
9	11 — 25	+ 56	+ 1.47	— .08
10	10 — 24	+ 84	+ 2.26	— .18
11	9 — 23	+ 112	+ 2.97	— .19
12	8 — 22	+ 140	+ 3.35	+ 12
13	7 — 21	+ 168	+ 3.97	+ 20

The “observed difference” above is the observed value of ρ ($n^2 - n'^2$).

Therefore we have:

$$\rho = + .02483 = .0004354 R$$

since one revolution R represents the space traversed by the star in $57^s.02$.

With this value of ρ we compute the corrections to the micrometer readings which follow. These are expressed in terms of one revolution of the screw:

<i>Micrometer.</i>	<i>Correction.</i>	<i>Micrometer.</i>	<i>Correction.</i>
7 & 33	+ .0736	14 & 26	+ .0157
8 32	.0627	15 25	.0109
9 31	.0527	16 24	.0070
10 30	.0435	17 23	.0039
11 29	.0353	18 22	.0017
12 28	.0279	19 21	.0004
13 27	.0213	20	.0000

These corrections are applied to the micrometer readings and a preliminary reduction carried out employing an approximate value of the screw, as follows:

From 1894, Jan. 19 to July 25,	$R = 50''.5352$
July 25 to Dec. 6,	50.5646
Dec. 6 to end of series,	50.5735

We can now write for each observed latitude an equation of the form

$$\sqrt{\rho} (\Delta \phi - (M - M') \Delta \frac{1}{2} R = n),$$

where $\Delta \phi$ and ΔR are corrections to the latitude and the assumed screw value, M and M' being the micrometer readings, corrected, of course, for progressive errors.

Fourteen sets of equations were formed for deriving corresponding values of $\Delta \phi$ and $\Delta \frac{1}{2} R$, the aim being to limit each series in respect to time, so that no considerable changes in those quantities need be apprehended.

The following example will illustrate the process :

Group.	Number.	No. of Obs.	$\sqrt{\rho}$	$M - M'$	n .	v .
I	1	10	1	— 15.3	— .49	— 06
	2	10	1	+ 4.2	+ .40	— 20
	3	9	1	— 14.2	— .57	+ 06
	4	11	1	— 3.5	— .37	+ 27
	5	11	1	+ 8.3	+ .32	+ 04
	6	10	1	+ 6.7	+ .30	— 01
	7	10	1	— 16.1	— .88	+ 30
	8	10	1	+ 6.4	+ .42	— 14
	9	10	1	— 5.3	— .01	— 16
	10	9	1	+ 21.4	+ .88	— 02
II	11	5	0.7	— 6.4	— .18	— 03
	12	5	0.7	— 5.1	— .23	+ 07
	13	4	0.7	+ 2.5	+ .56	— 43
	14	3	0.6	— 2.1	— .08	+ 03
	15	3	0.6	— 0.3	— .03	+ 05
	16	3	0.6	— 22.9	— .54	— 31
	17	3	0.6	— 11.7	— .35	— 06
	18	3	0.6	+ 20.9	+ .24	+ 60
	19	2	0.5	+ 16.0	+ .64	+ 01

From these equations,

$$\Delta \phi = + .0354$$

$$\Delta \frac{1}{2} R = + .0385$$

No use is made of $\Delta \phi$ in what follows.

All observations on one pair during the time embraced have been combined into one equation, the number being indicated in the third column.

The following table gives the results derived from these fourteen sets of equations. The adjusted value of $\Delta \frac{1}{2} R$ is explained in what follows :

	Date.	Mean Temperature.	Assumed $\frac{1}{2}R$.	Computed $\Delta\frac{1}{2}R$.	$\sqrt{\text{wt.}}$	Adjusted $\Delta\frac{1}{2}R$.	v.
1	1894. Jan. 19-Feb. 16	230.3	25.2676	+ .0385	1.	+ .0395	+ 10
2	Feb. 19-Mar. 18	35.2		+ .0382	1.0	+ .0369	- 13
3	Mar. 19-Apr. 30	47.3		+ .0351	0.7	+ .0342	- 9
4	May 8-June 11	60.7		+ .0317	1.0	+ .0313	- 4
5	June 12-July 5	72.4		+ .0263	1.0	+ .0287	+ 24
6	July 9-July 25	70.8		+ .0302	1.0	+ .0290	- 12
7	Aug. 5-Sept. 15	66.2	25.2823	- .0176	1.0	- .0100	+ 76
8	Oct. 2-Nov. 12	47.0		- .0083	1.0	- .0057	+ 26
9	Nov. 15-Dec. 6	35.5		- .0077	1.0	- .0032	+ 45
10	Dec. 25-Jan. 24	21.5	25.28675	- .0020	0.7	- .0045.5	- 25
11	1895. Jan. 27-Mar. 28	28.9		- .0040	1.0	- .0061.5	- 22
12	Apr. 10-Mar. 6	47.3		- .0065	0.7	- .0102.5	- 37
13	May 9-June 29	62.0		- .0123	1.0	- .0134.5	- 11
14	July 9-Aug. 19	67.6		- .0064	1.0	- .0147.5	- 83

A graphic construction showed that the values of $\frac{1}{2}R$ might be approximately represented by the expressions—

$$25''.2939 + x + (t - 21^{\circ}.5) z \text{ before July 25, 1894.}$$

$$25''.2647 + y + (t - 21^{\circ}.5) z \text{ after July 25, 1894.}$$

Solving the resulting equations for x , y and z , these expressions become—

$$25''.3075 - 2.21 (t - 21^{\circ}.5).$$

$$25''.2647 - 2.21 (t - 21^{\circ}.5).$$

t being the mean temperature and the coefficient 2.21 expressed in units of the fourth decimal place of the screw value.

From these expressions result the adjusted values given in the foregoing table.

The agreement is not altogether satisfactory, as shown by the residuals—in fact, it would, perhaps, have been better to make a strictly empirical adjustment. However, no appreciable difference could have followed in the final treatment of the latitudes.

No correction has been applied for periodic errors. A former attempt to determine this correction by means of Harkness' measuring engine was not successful; it seemed to be quite small, and it will be pretty effectually eliminated from the mean of a considerable number of measurements.

The Star List.

The derivation of the best attainable values of the star declinations employed has formed a relatively small part of a more extended undertaking, viz.: that of investigating the coördinates of all stars employed in the latitude work of the Sayre Observatory.

This subject will not be treated in detail at present, as the plan involves a more extended presentation in another place.

In the star list which follows the coördinates of those stars found in Newcomb's Fundamental Catalogue* were taken from that publication, but were reduced to the system of Auwers. The declinations of the remaining stars were deduced from what is believed to be practically all existing material, including observations made at the Lick Observatory, kindly furnished in advance of publication by R. H. Tucker. The reduction to Auwers' system has been applied in all cases where such was available. In case of a few of the newer series where this relation had not been investigated the Catalogue places were employed directly, but with a somewhat diminished weight.

It is not to be inferred that the system of Auwers is considered superior to that of Newcomb, but as this is the system more generally used in latitude work of this character, its employment here renders the results more directly comparable with those obtained elsewhere than would otherwise be the case. In the two pages which follow are found the mean coördinates for 1875, with elements of reduction to any epoch which appear to call for no explanation. The numbers are those of the British Association Catalogue. Those stars marked *N* were taken from Newcomb's Catalogue.

This list is followed by a second, giving the mean places for 1894 and 1895. The reduction to apparent place is as follows:

$$\frac{1}{2} (\delta + \delta') = \frac{1}{2} (\delta_0 + \delta'_0) + \frac{1}{2} (\mu' + \mu'_1) \tau + \frac{1}{2} (a' + a'_1) A + \frac{1}{2} (b' + b'_1) B + \frac{1}{2} (c' + c'_1) C + \frac{1}{2} (d' + d'_1) D$$

δ and δ' being the apparent declinations required,

δ_0 and δ'_0 the mean declinations here given.

A, *B*, *C* and *D* are taken from the American Ephemeris, where the significance of the remaining symbols may be found.

* Catalogue of Fundamental Stars for 1875 and 1900 reduced to an absolute system; Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac, Vol. VIII, Part II.

	Star.	Mag.	Right Ascension, 1875.	$\frac{da}{dt}$	$\frac{d^2a}{dt^2}$	μ	Declination, 1875.	$\frac{d\delta}{dt}$	$\frac{d^2\delta}{dt^2}$	$\frac{(100)^2}{6} \frac{d^3\delta}{dt^3}$	μ'	
Group I.	(1) 1751	5.5	h m s 5 29 55.00	+ 5.9977	+ 00027		° ' '' 65 37 34.15	+ 2.5911	— .008683	— .136	— .0337	
	1821	6.0	5 39 34.23	3.4478	+ 4	— .0006	15 46 17.27	1.7864	— 5015	— .021	+ .0011	
	(2) 1862	6.0	5 45 16.25	+ 3.4068	+ 3	— .0015	14 8 16.31	+ 1.2898	— 4960	— .014	+ .0018	
	1874	7.0	5 47 50.68	6.2172	+ 12		66 59 52.43	1.0174	— 9059	— .053	— .0457	
	(3) 1923	6.0	5 54 17.28	+ 4.3250	+ 3	+ .0105	42 54 45.79	+ 0.3511	— 6323	— .006	— .1487	
	1942	6.0	5 57 58.14	4.1343	+ 2	— .0010	38 29 28.93	0.1357	— 6028	+ .002	— .0420	
	(4) 1970	6.5	6 2 0.21	+ 3.6148	+ 1	— .0032	22 12 28.27	— 0.1745	— 5266	+ .006	+ .0008	
	2007	4.3	6 8 35.62	5.3013	— 4	+ .0009	59 8 10.51	— 0.7247	— 7724	+ .039	+ .0271	N
	(5) 2045	5.5	6 15 53.97	+ 5.2422	— 8	— .0050	58 28 56.15	— 1.3973	— 7613	+ .064	— .0072	
	2101	7.5	6 22 49.04	3.6267	— 1		22 37 32.72	— 1.9912	— 5254	+ .034	+ .0021	
	(6) 2139	6.7	6 27 57.13	+ 4.1295	— 5		38 32 37.82	— 2.4613	— 5967	+ .057	— .0215	
	2159	5.1	6 30 24.17	4.2894	— 7	— .0013	42 35 46.54	— 2.7119	— 6187	+ .069	— .0594	
	(7) 2187	5.1	6 35 11.25	+ 5.3101	— 20	— .0110	59 33 53.72	— 3.0706	— 7624	+ .135	— .0037	
	2233	6.0	6 44 8.54	3.5985	— 4	— .0015	21 54 23.21	— 3.8614	— 5133	+ .060	— .0298	
	(8) 2301	6.5	6 55 33.66	+ 3.8211	— 9	+ .0132	29 32 40.18	— 5.6255	— 5408	+ .091	— .8112	
	2341	5.6	7 3 38.30	4.6964	— 23		51 37 59.68	— 5.4925	— 6563	+ .171	+ .0048	
Group II.	(9) 2365	7.7	7 7 48.05	+ 5.2023	— 38	— .0100	59 8 14.81	— 5.8709	— 7218	+ .237	— .0243	
	2410	3.6	7 12 39.39	3.5900	— 7	— .0009	22 12 37.58	— 6.2573	— 4946	+ .095	— .0056	N
	(10) 2439	5.8	7 17 51.28	+ 6.3099	— 83	+ .0016	68 43 2.93	— 6.7301	— 8650	+ .433	— .0479	N
	2473	4.8	7 22 50.27	3.3439	— 5	— .0002	12 15 47.15	— 7.1017	— .004531	+ .088	— .0099	N
	(1) 4694	7.2	14 0 53.56	+ 2.6307	— 4		31 26 53.82	— 17.4277	+ .002028	+ .101	— .0994	
	4701	6.0	14 3 37.04	2.2455	— 6	— .0070	50 2 58.10	— 17.1566	+ 1751	+ .066	+ .0504	
	(2) 4728	6.0	14 9 21.04	+ 2.4259	— 5		42 6 22.85	— 17.0451	+ 1965	+ .079	— .1011	
	4758	6.0	14 14 39.72	2.4642	— 4		39 22 9.29	— 16.6933	+ 2064	+ .081	— .0024	
	(3) 4825	6.2	14 29 31.88	+ 2.4567	— 2		37 10 33.39	— 15.9886	+ 2244	+ .078	— .0536	
	4841	6.	14 33 30.82	2.2570	— 2	— .0086	44 10 55.50	— 15.6918	+ 2104	+ .064	+ .0293	
	(4) 4874	6.2	14 38 56.36	+ 1.4902	+ 10	+ .0115	61 47 42.71	— 15.4542	+ 1466	+ .045	— .0323	
	4905	4.6	14 45 37.48	2.7670	+ 2	+ .0100	19 37 14.04	— 15.1218	+ 2743	+ .102	— .0803	N
	(5) 4926	5.7	14 50 19.27	+ 2.8287	+ 4	— .0020	14 57 9.49	— 14.7674	+ 2853	+ .106	— .0009	N
	4949	4.9	14 55 36.08	0.9348	+ 29	— .0124	66 25 50.42	— 14.4330	+ 995	+ .058	+ .0170	N
	(6) 4974	4.9	14 59 40.35	+ 1.9810	+ 2	— .0376	48 8 30.82	— 14.1646	+ 2062	+ .049	+ .0361	N
	5000	7.2	15 5 34.98	2.4302	— 1		33 33 11.89	— 13.8332	+ 2626	+ .070	— .0023	
	(7) 5072	5.3	15 16 48.30	+ 2.4004	+ 1	— .0050	33 22 55.55	— 13.0931	+ 2701	+ .065	+ .0104	
	5113	6.7	15 25 24.60	1.9067	+ 4		48 8 35.78	— 12.5294	+ 2226	+ .044	— .0050	
	(8) 5147	5.9	15 29 10.63	+ 0.8277	+ 26	— .0140	64 37 46.26	— 12.1847	+ 993	+ .057	+ .0806	
	5180	5.8	15 35 14.29	2.7536	+ 4	— .0005	16 25 44.63	— 11.8507	+ 3291	+ .082	— .0093	
	(9) 5210	6.5	15 39 26.97	+ 1.6301	+ 7	— .0040	52 45 22.11	— 11.5069	+ 1989	+ .038	+ .0352	
	5236	6.0	15 43 25.40	2.4704	+ 3		28 32 28.75	— 11.2549	+ 3030	+ .062	+ .0011	
	(10) 5271	4.6	15 48 21.29	+ 2.0728	+ 2	+ .0400	42 48 8.18	— 10.2675	+ 2634	+ .042	+ .6288	N
	5295	5.5	15 51 14.70	2.1821	+ 3	+ .0037	38 18 32.54	— 10.5979	+ 2744	+ .046	+ .0844	

Star.	Mag.	Right Ascension, 1875.	$\frac{da}{dt}$	$\frac{d^2a}{dt^2}$	μ	Declination, 1875.	$\frac{d\delta}{dt}$	$\frac{d^2\delta}{dt^2}$	$\frac{(100)^3}{6} \frac{d^3\delta}{dt^3}$	μ'			
Group III.	(1) 5941 6006	2.3 4.9	^{h m s} 17 29 7.97 17 37 43.11	+ 2.7828 - 0.3592	+ 00003 + 11	+ .0080 + .0018	12 39 9.19 68 48 55.94	- 2.9184 - 1.6344	+ .004045 - 510	- .021 + .027	- .2256 + .3151	N N	
	(2) 6122 6143	5.8 3.7	17 57 21.18 18 1 25.44	- 1.0456 + 2.8429	+ 6 + 2	+ .0006 - .0045	72 0 59.20 9 32 51.52	- 0.2394 + 0.2215	- 1523 + 4139	+ .016 - .002	- .0078 + .0969	N	
	(3) 6193 6203	6.0 5.3	18 8 54.62 18 11 45.55	+ 1.9987 + 1.8644	+ 2 + 2	- .0017 - 0007	38 44 22.70 42 7 3.70	+ 0.7838 + 1.0309	+ 2907 + 2710	- .002 - .002	+ .0043 + .0024	N	
	(4) 6232 6258	6.5 6.0	18 15 2.80 18 18 33.05	+ 2.3170 1.4124	+ 2 + 1	+ .0030	29 36 47.62 51 14 28.25	+ 1.3259 1.6091	+ 3370 + 2046	- .006 - .002	+ .0102 - .0122		
	(5) 6373 6387	6.5 4.3	18 36 53.24 18 40 16.96	+ 0.7307 2.5800	- 4 + 2	- 0020	60 35 43.03 20 25 41.21	+ 3.2589 3.1726	+ 1038 + 3687	- .012 - .022	+ .0451 - .3341	N	
	(6) 6476 6491	6.0 3.3	18 51 29.30 18 54 16.09	+ 1.5800 2.2432	0 + 1	- .0085 - 0005	48 42 13.81 32 31 9.37	+ 4.3436 4.7073	+ 2215 + 3159	- .012 - .023	- .1240 + .0029	N	
	(7) 6534 6579	5.7 6.0	19 0 12.14 19 8 50.81	+ 2.2792 + 1.5553	+ 1 - 3	- .0153	31 33 32.09 49 37 16.27	+ 5.1369 6.5575	+ 3188 + 2120	- .025 - .022	- .0706 + .6234		
	(8) 6599 6656	4.5 6.5	19 12 1.82 19 19 59.51	+ 2.0805 + 1.8974	+ 1 + 1	- .0015 + 0027	37 54 43.78 43 8 42.92	+ 6.2136 6.8221	+ 2857 + 2574	- .026 - .024	+ .0140 - .0362	N	
	(9) 6697 6740	3.9 4.0	19 26 33.26 19 34 26.30	+ 1.5140 + 2.3667	- 2 + 1	+ .0021 - 0031	51 27 51.02 29 51 58.67	+ 7.5200 + 8.0786	+ 2028 + 3125	- .024 - .042	+ .1250 + .0468	N	
	Group IV.	(1) 7509 7522	7.3 5.8	21 28 59.03 21 32 16.21	- 0.1756 + 3.0046	- 107 - 2	+ 0056	75 51 14.56 5 12 30.91	+ 15.8451 16.0610	+ 225 + 2569	- .160 - .135	- .0107 + .0308	
		(2) 7561 7597	2.5 5.0	21 38 2.80 21 41 32.10	+ 2.9467 0.7568	- 1 - 41	+ 0016 - 0126	9 18 9.89 71 44 50.27	+ 16.3381 16.4608	+ 2426 + 546	- .129 - .065	+ .0093 - .0433	N
		(3) B.D.59.2444 7712	7.4 6.0	21 55 23.04 22 1 58.16	+ 1.8887 + 2.8144	+ 7 + 5	- 0038	59 41 56.30 21 5 42.22	+ 17.1664 17.3875	+ 1351 + 1944	- .048 - .119	+ .0044 - .0655	
(4) 7760 7796		6.2 5.1	22 7 47.39 22 15 21.95	+ 1.3892 2.9526	- 10 + 2	+ .0011	69 30 55.01 11 34 33.48	+ 17.7057 18.0168	+ 877 + 1822	- .042 - .139	+ .0075 + .0166	N	
(5) 7820 7843		5.0 5.5	22 19 27.00 22 24 18.86	+ 2.4198 2.7378	+ 15 + 11	- .0027 + .0034	48 50 35.16 31 55 59.80	+ 18.1416 18.3258	+ 1419 + 1542	- .080 - .113	- .0133 - .0058	N	
(6) 7915 7932		6.0 5.1	22 35 53.01 22 38 31.18	+ 2.6777 2.6642	+ 15 + 16	+ 0020 - 0012	39 34 22.44 41 9 49.01	+ 18.7157 18.8149	+ 1322 + 1271	- .107 - .106	- .0029 + .0148	N	
(7) 7962 7978		6.0 6.7	22 44 43.70 22 47 28.86	+ 2.6935 2.7275	+ 17 + 16	- .0018	41 17 30.61 39 30 12.46	+ 18.9762 19.0465	+ 1185 + 1155	- .110 - .114	- .0061 - .0121		
(8) 8024 8052		6.5 4.5	22 56 14.00 23 1 1.50	+ 2.5188 2.9141	+ 26 + 11	- 0010	56 26 3.21 24 47 38.07	+ 19.2766 19.3660	+ 926 + 998	- .092 - .140	- .0064 - .0279		
(9) 8078 8122		5.2 6.8	23 5 25.57 23 13 22.04	+ 3.0270 2.1787	+ 3 + 40	- 0007 - 0096	8 2 29.52 73 0 21.60	+ 19.5022 19.6084	+ 957 + 555	- .157 - .063	+ .0139 - .0321	N	
(10) 8195 8229		6.0 4.3	23 25 8.80 23 32 0.62	+ 2.9332 2.9250	+ 21 + 25	+ 0223 + 0024	38 32 58.87 42 34 34.12	+ 19.7497 19.9075	+ 567 + 434	- .144 - .144	- .0731 + .0026	N	
(11) 8252 8284		6.5 6.0	23 37 0.68 23 43 19.97	+ 2.8950 3.0239	+ 35 + 16	- 0030 + 0036	52 27 33.04 28 8 47.79	+ 19.9492 20.0206	+ 336 + 235	- .139 - .159	- .0042 + .0194		
(12) 8317 8324		7.5 4.8	23 49 18.36 23 51 24.51	+ 2.9744 3.0464	+ 44 + 15	- 0028 - 0031	56 42 59.50 24 26 47.38	+ 20.0216 20.0143	+ 116 + 80	- .151 - .163	- .0108 - .0258	N	

Pair.	α1894.			1895.	δ1894.			1895.	Zenith Distance, 1894.			S-N.			
Group I.	(1)	h	m	s	s	°	'	"	"	°	'	"	N	'	"
		5	31	49.01	55.01	65	38	21.82	24.24	25	1	58	S	—	12 24
	5	40	39.75	43.20	15	46	50.30	51.99	24	49	34				
	(2)	5	46	20.98	24.39	14	8	39.92	41.11	26	27	44	S	+	3 58
		5	49	48.83	55.05	67	0	10.13	10.97	26	23	46	N		
	(3)	5	55	39.46	43.79	42	54	51.33	51.55	2	18	27	N	—	11 33
		5	59	16.70	20.83	38	29	30.42	30.44	2	6	54	S		
	(4)	6	3	8.89	12.50	22	12	24.01	23.73	18	24	0	S	—	2 31
		6	10	16.34	21.64	59	2	55.35	54.47	18	26	31	N		
	(5)	6	17	33.56	38.80	53	28	28.23	26.68	17	52	4	N	+	7 26
		6	23	57.95	61.58	22	36	53.95	51.85	17	59	30	S		
	(6)	6	29	15.58	19.71	33	31	49.98	47.40	2	4	34	S	+	6 4
		6	31	45.66	49.95	42	34	53.90	51.06	1	58	30	N		
	(7)	6	36	52.11	57.42	59	32	54.00	50.78	18	56	30	N	—	13 15
		6	45	11.90	15.50	21	53	8.92	4.96	18	43	15	S		
	(8)	6	56	46.24	50.06	29	30	52.32	46.59	11	5	32	S	+	5 42
		7	5	7.49	12.18	51	36	14.14	8.52	10	59	50	N		
	(9)	7	9	26.83	32.03	59	6	21.97	15.95	18	29	58	N	—	4 12
		7	13	47.59	51.18	22	10	37.80	31.44	18	25	46	S		
	(10)	7	19	51.02	57.31	68	40	53.50	46.60	28	4	30	N	+	18 23
7		23	53.79	57.13	12	13	31.40	24.21	28	22	53	S			
Group II.	(1)	14	1	44.11	46.77	31	21	23.06	5.67	9	15	1	S	—	6 7
		14	4	19.69	21.93	49	57	32.44	15.32	9	21	8	N		
	(2)	14	10	7.12	9.55	42	0	59.35	42.34	1	24	35	N	—	5 3
		14	15	26.53	28.99	39	16	52.49	35.84	1	19	32	S		
	(3)	14	30	18.55	21.01	37	5	30.01	14.07	3	30	54	S	+	1 20
		14	34	13.70	15.96	44	5	57.73	42.08	3	29	34	N		
	(4)	14	39	24.69	26.18	61	42	49.34	33.92	21	6	25	N	—	2 28
		14	46	30.06	32.83	19	32	27.22	12.15	21	3	57	S		
	(5)	14	51	13.02	15.85	14	52	29.42	14.71	25	43	55	S	—	0 57
		14	55	53.89	54.83	66	21	16.37	1.96	25	44	52	N		
	(6)	15	0	17.99	19.97	48	3	62.06	47.94	7	27	38	N	—	20 4
		15	6	21.15	23.58	33	28	49.53	35.76	7	7	34	S		
	(7)	15	17	33.91	36.31	33	18	47.27	34.23	7	17	37	S	—	10 37
		15	26	0.83	2.74	48	4	38.12	25.64	7	28	14	N		
	(8)	15	29	26.40	27.23	64	33	54.93	42.76	23	57	31	N	+	16 53
		15	36	6.62	9.37	16	21	60.06	48.27	24	14	24	S		
	(9)	15	39	57.96	59.59	52	41	43.84	32.37	12	5	20	N	+	2 9
		15	44	12.34	14.81	28	28	55.45	44.26	12	7	29	S		
	(10)	15	49	0.68	2.75	42	44	53.57	43.36	2	8	30	N	+	12 42
		15	51	56.17	58.35	38	15	11.67	1.13	2	21	12	S		

	Pair.	$\alpha 1894.$			1895.	$\delta 1894.$			1895.	Zenith Distance, 1894.			S-N.
		h	m	s		°	'	"		°	'	"	
Group III.	(1)	17	30	0.85	3.63	12	38	14.47	11.63	27	58	10	S
		17	37	34.30	33.94	68	48	24.79	23.15	28	12	1	N
	(2)	17	57	1.33	0.29	72	0	54.38	54.11	31	24	30	N
		18	2	19.46	22.30	9	32	56.48	56.78	31	3	28	S
	(3)	18	9	32.60	34.60	38	44	38.12	38.96	1	51	46	S
		18	12	20.98	22.84	42	7	23.77	24.86	1	31	0	N
	(4)	18	15	46.83	49.15	29	37	13.42	14.81	10	59	11	S
		18	18	59.89	61.30	51	14	59.19	60.84	10	38	35	N
	(5)	18	37	7.12	7.85	60	36	45.14	48.42	20	0	21	N
		18	41	5.98	8.56	20	26	42.15	45.40	20	9	42	S
	(6)	18	51	59.32	60.90	48	43	36.73	41.12	8	7	13	N
		18	54	58.71	60.95	32	32	39.38	44.15	8	3	45	S
	(7)	19	0	55.45	57.73	31	35	10.27	15.47	9	1	14	S
		19	9	20.36	21.91	49	39	21.24	27.84	9	2	57	N
	(8)	19	12	41.35	43.43	37	56	42.35	48.62	2	39	42	S
		19	20	35.56	37.46	43	10	53.01	59.88	2	34	29	N
	(9)	19	27	2.02	3.53	51	30	14.27	21.83	10	53	50	N
		19	35	11.27	13.64	29	54	32.73	40.87	10	41	51	S
Group IV.	(1)	21	28	55.50	55.30	75	56	15.58	31.42	35	19	52	N
		21	33	13.29	16.29	5	17	36.53	52.64	35	18	47	S
	(2)	21	38	58.79	61.74	9	23	20.75	37.14	31	13	3	S
		21	41	46.41	47.16	71	50	3.13	19.60	31	13	39	N
	(3)	21	55	58.94	60.83	59	47	22.71	39.90	19	10	59	N
		22	2	51.64	54.46	21	11	12.93	30.36	19	25	11	S
	(4)	22	8	13.77	15.16	69	36	31.58	49.30	29	0	8	N
		22	16	18.05	21.00	11	40	16.13	34.18	28	56	8	S
	(5)	22	20	13.00	15.42	48	56	20.11	38.28	8	19	56	N
		22	25	10.90	13.64	32	1	48.26	66.62	8	34	36	S
	(6)	22	36	43.91	46.59	39	40	18.28	37.02	0	56	6	S
		22	39	21.83	24.50	41	15	46.72	65.56	0	39	23	N
	(7)	22	45	34.91	37.61	41	23	31.37	50.37	0	47	7	N
		22	48	20.71	23.44	39	36	14.55	33.62	1	0	9	S
	(8)	22	57	1.90	4.42	56	32	9.63	28.93	15	55	46	N
		23	1	56.89	59.81	24	53	46.20	65.59	15	42	38	S
	(9)	23	6	23.09	26.12	8	8	40.24	59.76	32	27	44	S
		23	14	3.51	5.69	73	6	34.26	53.88	32	30	10	N
	(10)	23	26	4.57	7.51	38	39	14.22	33.98	1	57	10	S
		23	32	56.24	59.17	42	40	52.44	72.36	2	4	28	N
	(11)	23	37	55.75	58.65	52	33	52.13	72.09	11	57	28	N
		23	44	17.45	20.48	28	15	8.22	28.25	12	21	16	S
	(12)	23	50	14.95	17.93	56	49	19.94	39.96	16	12	56	N
		23	52	22.42	25.47	24	33	7.66	27.68	16	3	16	S

The Latitude Observations.

The details of the latitude determination are found in the pages following. The expression for the latitude is—

$$\phi = \frac{1}{2}(\delta + \delta') + \frac{1}{4}R(M - M') + \frac{1}{4}d[(n - n') - (s' - s)] + \frac{1}{2}(m + m') + \frac{1}{2}(r - r')$$

M and M' are the corrected readings of the micrometer.

n, s, n', s' , the readings of the north and south end of the level for the two stars.

m, m' , corrections for curvature.

r, r' , corrections for refraction.

The contents of most of the columns will be sufficiently explained by the headings.

Column P gives the position of the instrument.

D , direct, the telescope east when pointing south of the zenith.

R , reverse, the telescope west when pointing south of the zenith.

Column C gives the correction for progressive errors of the screw.

Levels A and B , the value of $(n - n') - (s' - s)$ for each level.

Column δ gives the correction required on account of $\Delta \frac{1}{2}R$, found on page 83. In case of those pairs observed with threads II and IV this is combined with the correction for the amount by which the distance between those threads differs from twenty revolutions of the screw.

Throughout this table the footnote references *a*, *b*, *c*, and *d* indicate as follows: *a*=e. e. f.; *b*=definition very poor; *c*=levels discordant; *d*=clouds.

1894	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther- mom.
						A	B		Micrometer.	δ	l	r	Mer		
Jan. 19	I	1 D	27.8237	12.6470	+ 31	-2.9	-3.4	40 42 48.42	-6 23.56	- 60	- 90	-13	8	40 36 23.31	30.6
			24.6583	20.4470	+ 94	-4.0	-2.0	40 34 36.71	+1 46.65	+ 17	- 90	+ 4	8	22.75	
			30.1117	15.9673	+374	+1.2	+ .8	40 42 22.54	-5 58.34	- 56	+ 30	-10	6	23.90	
			18.5863	22.0447	+ 8	+1.3	+ .1	40 37 50.67	-1 27.41	- 14	+ 23	- 3	7	23.39	31.6
			17.1530	25.5403	+ 97	- .2	-1.3	40 32 51.48	+3 32.17	+ 33	- 20	+ 7	7	23.92	
			25.1847	18.3807	+106	-4.5	-4.4	40 33 31.80	+2 52.19	+ 26	-1.28	+ 5	6	23.08	
			29.3270	13.2580	+191	+1.0	+1.0	40 43 10.77	-6 46.48	- 64	+ 29	-12	7	23.89	
			23.8183	17.3970	+ 34	-2.9	-2.9	40 33 41.17	+2 42.34	+ 25	- 84	+ 5	6	23.03	30.6
			22.2030	16.9083	- 21	-1.6	-2.0	40 38 37.24	-2 13.73	- 21	- 51	- 4	7	22.82	
			7.5603 ⁱⁱ	29.0650 ^{iv}	- 24	-1.5	-1.2	40 27 19.29	+9 3.31	+ 83	- 40	+20	9	23.32	29.6
Jan. 25	I	1 R	14.0800	29.3317	+227	+ .9	+ .7	40 42 49.16	-6 25.95	- 60	+ 26	-13	8	22.82	21.5
			19.9213	24.0473	+ 70	+1.9	+ .9	40 34 37.46	+1 44.43	+ 17	+ 42	+ 4	8	22.60	
			14.6907	23.9170	+222	- .1	+ .4	40 42 23.36	-6 0.03	- 56	+ 3	-10	6	22.76	21.0
			24.2633	20.7807	+ 77	+1.5	+1.6	40 37 51.48	-1 28.32	- 14	+ 44	- 3	7	23.50	21.0
			24.8627	16.5750	+ 52	+1.6	+1.5	40 32 52.30	+3 29.54	+ 33	+ 45	+ 7	7	22.76	
			16.3180	23.0093	- 22	+1.7	+1.2	40 33 32.66	+2 49.02	+ 26	+ 45	+ 5	6	22.50	
			12.1583	23.3080	+ 32	+ .7	+ .6	40 43 11.61	-6 48.15	- 64	+ 18	-12	7	22.95	
			17.2093	23.5427	+ 20	+2.0	+1.5	40 33 42.02	+2 40.08	+ 25	+ 52	+ 5	6	22.98	20.2
			18.1737	23.5317	+ 40	- .3	+ .3	40 38 38.11	-2 15.48	- 21	- 1	- 4	7	22.44	
			31.7237 ^{iv}	10.2847 ⁱⁱ	+ 12	-2.1	- .2	40 27 20.05	+9 1.74	+ 83	- 36	+20	9	22.55	20.6
Jan. 27	I	1 D	27.6193	12.3807	- 1	- .7	-2.2	40 42 49.29	-6 25.04	- 60	- 41	-13	8	23.19	26.8
			22.0680	17.9097	0	+1.1	+ .1	40 34 37.62	+1 45.07	+ 17	+ 17	+ 4	8	23.15	
			27.3453	13.1350	+ 30	-1.0	+1.2	40 42 23.54	-5 59.14	- 56	- 31	-10	6	23.49	26.4
			17.1290	20.6350	- 34	+ .6	- .3	40 37 51.66	-1 28.50	- 14	+ 6	- 3	7	23.12	
			15.3263	23.6640	- 37	0	+ .2	40 32 52.49	+3 30.58	+ 33	+ 2	+ 7	7	23.56	
			23.2457	16.5013	- 7	- .8	-1.8	40 33 32.86	+2 50.40	+ 26	- 37	+ 5	6	23.26	26.8
			27.9270	11.8237	- 22	-1.9	-1.8	40 43 11.80	-6 46.84	- 64	- 55	-12	7	23.72	26.6
			23.3103	16.9490	+ 7	-1.3	- .5	40 33 42.24	+2 40.75	+ 25	- 26	+ 5	6	23.09	
			21.9970	17.6553	- 8	+ .2	+ .9	40 38 38.33	-2 14.95	- 21	+ 14	- 4	7	23.34	
			8.3810 ⁱⁱ	29.8150 ^{iv}	- 11	0	0	40 27 20.25	+9 1.56	+ 83	0	+20	9	22.93	
Jan. 27	II	1 D	15.6303	22.0747	- 64	-1.5	-1.2	40 39 6.40	-2 42.67	- 25	- 41	- 5	6	23.08	23.8
			23.7070	18.5513	+ 34	+ .9	+ .5	40 38 34.01	-2 10.36	- 20	+ 22	- 3	6	23.70	
			21.9730	19.5720	+ 15	+ .7	- .1	40 35 21.41	+1 0.71	+ 10	+ 10	+ 2	6	22.40	
			19.7397	17.6017	- 25	- .6	+1.0	40 37 16.62	- 53.95	- 8	+ 3	- 2	7	22.67	
			19.4913	19.8543	- 1	+2.2	+1.7	40 36 31.45	- 9.17	- 1	+ 57	- 0	9	22.93	22.6
			31.2783 ^{iv}	8.3383 ⁱⁱ	- 5	+1.6	+1.6	40 46 2.72	-9 39.63	- 88	+ 48	-17	6	22.58	
			14.6627	26.3770	+ 53	- .5	+ .6	40 41 19.42	-4 56.13	- 46	+ 1	- 8	6	22.82	
			9.5983 ⁱⁱ	30.4910 ^{iv}	0	+ .9	- .6	40 27 35.41	+8 47.91	+ 81	+ 7	+17	8	24.45	22.6
			12.5893	27.8300	+ 26	+ .5	+ .8	40 42 49.35	-6 25.16	- 60	+ 18	-13	8	23.72	24.0
			19.0140	23.1793	+ 41	+ .1	- .5	40 34 37.67	+1 45.35	+ 17	- 5	+ 4	8	23.26	
Jan. 28	I	1 R	13.6527	27.8787	+ 91	- .1	+ .8	40 42 23.60	-5 59.69	- 56	+ 9	-10	6	23.40	
			23.6663	20.1833	+ 58	+1.5	+1.5	40 37 51.73	-1 28.15	- 14	+ 43	- 3	7	23.91	
			23.9243	15.5990	- 19	- .3	+ .2	40 32 52.56	+3 30.31	+ 33	- 2	+ 7	7	23.32	<i>a</i>
			17.0703	23.7873	+ 26	- .4	- .9	40 33 32.95	+2 49.79	+ 26	- 20	+ 5	6	22.91	
			13.7950	29.9000	+259	-1.6	- .9	40 43 11.88	-6 47.59	- 64	- 38	-12	7	23.22	22.3
			24.8433	9.5513	-373	-1.8	-1.0	40 42 49.44	-6 25.45	- 60	- 40	-13	8	22.94	32.6
			22.4630	18.3093	+ 14	-1.2	-2.9	40 34 37.78	+1 44.99	+ 17	- 56	+ 4	8	22.50	
Jan. 30	I	1 D	26.3643	12.0900	- 96	+1.4	+ .5	40 42 23.73	-6 0.43	- 56	+ 29	-10	6	22.99	
			17.9990	21.5027	- 6	- .8	-1.5	40 37 51.85	-1 28.51	- 14	- 34	- 3	7	22.90	
			16.8840	25.1503	+ 73	+ .8	+ .8	40 32 52.69	+3 29.05	+ 33	+ 24	+ 7	7	22.45	32.3
			23.8970	17.1903	+ 32	- .6	-1.2	40 33 33.09	+2 49.54	+ 26	- 25	+ 5	6	40 36 22.75	32.4
			28.1793	12.0373	+ 16	-2.0	- .5	40 43 12.02	-6 47.91	- 64	- 38	-12	7	23.04	31.6
			22.1067	15.7443	- 61	-1.0	-1.0	40 33 42.48	+2 40.61	+ 25	- 29	+ 5	6	23.16	
			22.5473	17.2050	- 6	-1.2	-1.7	40 38 38.56	-2 14.97	- 21	- 41	- 4	7	23.00	
			8.1260 ⁱⁱ	29.5650 ^{iv}	- 13	+ .5	+ .7	40 27 20.46	+9 1.68	+ 83	+ 17	+20	9	23.43	31.1

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
Jan.															
31	I	1 R	11.4543	26.7167	-124	-.4	-.9	40 43 49.50	-6 25.33	- 60	- 20	-13	8	40 36 23.32	28.
		2	17.9183	22.1020	0	-2.1	-2.1	40 34 37.84	+1 45.71	+ 17	- 62	+ 4	8	23.22	
		4	22.3530	18.8797	+ 18	+ .6	-1.0	40 37 51.93	-1 27.81	- 14	- 3	- 3	7	23.99	28.7
		5	24.9987	16.6793	+ 59	-2.0	-1.1	40 32 52.76	+3 30.36	+ 33	- 45	+ 7	7	23.14	
		6	16.7357	23.4720	+ 6	-.3	-1.2	40 33 33.18	+2 50.22	+ 26	- 22	+ 5	6	23.55	
		7	12.4090	28.5417	+ 66	-.6	-.0	40 43 12.10	-6 47.80	- 64	- 8	-12	7	23.53	
		8	17.7410	24.0937	+ 51	+ .4	+ .6	40 33 42.56	+2 40.65	+ 25	+ 12	+ 5	6	23.69	27.5
		9	18.1583	23.5107	+ 40	-.4	-.2	40 38 38.65	-2 15.34	- 21	- 9	- 4	7	23.04	
Feb.		10	32.2200 ^{iv}	10.8167 ⁱⁱ	+ 19	+1.2	+1.8	40 27 20.54	+9 0.86	+ 83	+ 42	+20	9	22.94	28.4
1	II	1 R	22.9023	16.4937	- 18	-2.2	-2.2	40 39 5.94	-2 41.88	- 25	- 66	- 5	6	23.16	23.4
		2	18.4417	23.5673	+ 45	-1.0	-.4	40 38 33.51	-2 9.63	- 20	- 21	- 3	6	23.50	
		3	19.4670	21.9317	+ 14	-.4	+ .1	40 35 20.83	+1 2.31	+ 10	- 5	+ 2	6	23.27	
		4	20.5023	22.5873	+ 28	-.1	-.6	40 37 16.04	- 52.75	- 8	- 9	- 2	7	23.17	23.2
		5	21.7963	21.4990	+ 4	+ .2	+ .3	40 36 30.93	- 7.52	- 1	- 1	0	9	23.48	
		6	9.1133 ⁱⁱ	31.9680 ^{iv}	+ 17	-1.7	-2.0	40 46 2.04	-9 37.53	- 88	- 56	-17	6	22.96	
		7	26.7263	15.0633	+ 92	+1.7	+ .5	40 41 18.66	-4 54.93	- 46	+ 33	- 8	6	23.58	23.1
		8	31.5433 ^{iv}	10.6517 ⁱⁱ	+ 8	+ .4	0	40 27 34.67	+8 47.90	+ 81	+ 8	+17	8	23.71	
Feb.		10	27.2713 ^{iv}	11.2683 ⁱⁱ	+ 25	-1.2	-1.5	40 29 38.32	+6 44.42	+ 61	- 38	+11	7	23.15	
4	II	1 D	16.1913	22.6443	- 33	+1.1	+1.9	40 39 5.63	-2 42.97	- 25	+ 45	- 5	6	22.87	13.2b
		2	23.3880	18.2530	+ 37	+1.1	+ .2	40 38 33.17	-2 9.84	- 20	+ 20	- 3	6	23.36	
Feb.		3	20.8503	18.3943	- 9	-1.3	-.9	40 35 20.44	+1 2.03	+ 10	- 33	+ 2	6	22.32	12.3
5	I	1 D	27.4927	12.1777	- 22	+ .5	+ .3	40 42 50.00	-6 26.92	- 60	+ 12	-13	8	22.55	18.2
		2	22.6073	18.4380	+ 19	-1.5	-2.4	40 34 38.37	+1 45.40	+ 17	- 55	+ 4	8	23.51	
		4	17.8907	21.4060	- 10	-1.6	-1.1	40 37 52.49	-1 28.80	- 14	- 40	- 3	7	23.19	
		5	17.0087	25.3177	+ 85	-1.3	-1.5	40 32 53.36	+3 30.16	+ 33	- 40	+ 7	7	23.59	15.8
		6	24.2170	17.4928	+ 50	-1.8	-1.7	40 33 33.81	+2 50.03	+ 26	- 53	+ 5	6	23.68	
		7	28.7087	12.5730	+ 90	-1.5	-1.1	40 43 12.72	-6 47.94	- 64	- 38	-12	7	23.71	16.6
		8	23.2483	16.9587	+ 7	-.4	-.7	40 33 43.22	+2 38.94	+ 25	- 18	+ 5	6	22.34	
		9	23.1897	17.8510	+ 25	-1.7	-2.0	40 38 39.30	-2 14.96	- 21	- 52	- 4	7	23.64	
		10	9.2247 ⁱⁱ	30.6597 ^{iv}	0	-1.7	-.6	40 27 21.14	+9 1.61	+ 83	- 34	+20	9	23.53	15.2
Feb.		6	12.7857	28.0720	+ 57	-.1	-.3	40 42 50.11	-6 26.39	- 60	- 7	-13	8	23.00	22
		2	18.3510	22.4823	+ 16	-3.2	-4.6	40 34 58.48	+1 44.43	+ 17	-1.11	+ 4	8	22.09	
		3	13.2433	27.5070	+ 47	-.9	-1.2	40 42 24.52	-6 0.53	- 56	- 30	-10	6	23.09	
		4	22.9643	19.4523	+ 36	+ .7	+ .4	40 37 52.64	-1 28.83	- 14	+ 16	- 3	7	23.87	23.6
		5	24.2867	16.0197	+ 13	+ .3	+2.1	40 32 53.49	+3 28.92	+ 33	+ 32	+ 7	7	23.20	23.5
		6	17.3513	24.0637	+ 41	+ .3	+ .5	40 33 33.95	+2 49.71	+ 26	+ 10	+ 5	6	24.13	
		7	13.0087	29.1663	+154	- 0	- 0	40 43 12.87	-6 48.65	- 64	- 0	-12	7	23.53	23.0
		8	17.7067	24.0000	+ 47	+1.6	+1.4	40 33 43.37	+2 39.14	+ 25	+ 45	+ 5	6	23.32	
		9	17.6847	23.0847	+ 18	+ .1	0	40 38 39.45	-2 16.49	- 21	+ 3	- 4	7	22.81	a
		10	32.4257 ^{iv}	11.0243 ⁱⁱ	+ 23	- 0	-.2	40 27 21.29	+9 0.82	+ 83	- 2	+20	9	23.21	23.4
Feb.		11	27.9173	12.6390	+ 38	-1.8	-2.5	40 42 50.39	-6 26.14	- 60	- 60	-13	8	23.00	33.5
		2	22.9650	18.8243	+ 32	-1.5	0	40 34 38.81	+1 44.71	+ 17	- 24	+ 4	8	23.57	
		3	28.1970	13.8757	+130	+2.6	+1.3	40 42 24.90	-6 2.19	- 56	+ 57	-10	6	22.68	
		4	18.0300	21.5780	- 5	-.9	-2.3	40 37 53.04	-1 29.64	- 14	- 44	- 3	7	22.86	33.3
		5	16.5260	24.7923	+ 47	-.5	-.1	40 32 53.92	+3 28.99	+ 33	- 11	+ 7	7	23.27	
		7	29.4487	13.2903	+193	-.5	-1.9	40 43 13.35	-6 48.72	- 64	- 31	-12	7	23.63	
		8	23.7220	17.4473	+ 32	-.5	-1.5	40 33 43.92	+2 38.63	+ 25	- 27	+ 5	6	22.64	32.1
		9	23.9587	18.5483	+ 59	+ .8	+2.2	40 38 40.00	-2 16.80	- 21	+ 42	- 4	7	23.38	32.6
		10	9.8677 ⁱⁱ	31.2503 ^{iv}	+ 4	+ .2	-.1	40 27 21.82	+9 0.30	+ 83	+ 1	+20	9	23.25	
		II 1 D	15.6027	22.0210	- 69	-.8	+ .4	40 39 5.44	-2 42.00	- 25	- 10	- 5	6	23.10	25.2
Feb.		2	23.9343	18.8043	+ 60	+ .9	+ .4	40 38 32.92	-2 9.77	- 20	+ 21	- 3	6	23.19	24.8
15	I	1 R	12.0227	27.3173	- 45	-.8	-1.4	40 42 50.54	-6 26.34	- 60	- 32	-13	8	23.23	27.4
		2	18.6237	22.7487	+ 24	-1.8	-.4	40 34 38.99	+1 44.29	+ 17	- 34	+ 4	8	23.23	
		3	13.3550	27.6370	+ 62	-.6	-.7	40 42 25.12	-6 1.03	- 56	- 17	-10	6	23.32	
		4	23.8620	20.3357	+ 65	-1.3	-.6	40 37 53.27	-1 29.27	- 14	- 27	- 3	7	23.63	26.5

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.			
						A	B		Micrometer.	δ	l	r	Mer					
Feb.	15	I	5	R	24.9280	16.6793	+ 56	+ .4	— .2	40 32 54.17	+ 3 28.57	+ 33	+ 2	+ 7	7	40 36 23.23	○	
			6		17.2970	23.9450	+ 36	— 1.1	— .3	40 33 34.71	+ 2 48.07	+ 26	— 21	+ 5	6	22.94	25.4	
			7		13.0220	29.2033	+ 155	— .6	— 1.4	40 43 13.62	— 6 49.25	— 64	— 29	— 12	7	23.39	24.8	
			8		17.5477	23.7933	+ 37	+ 1.0	+ 1.3	40 33 44.23	+ 2 37.90	+ 25	+ 33	+ 5	6	22.82		
			9		18.4893	23.9123	+ 56	— .2	+ .2	40 38 40.31	— 2 17.17	— 21		0	— 4	7	22.96	25.3
Feb.	16	I	1	D	26.2933	11.0240	— 177	+ 1.1	— 2.2	40 42 50.62	— 6 25.37	— 60	— 11	— 13	8	[24.49]	16.3c	
			2		23.2107	19.0543	+ 41	— 4.3	— 1.0	40 34 39.07	+ 1 45.13	+ 17	— 82	+ 4	8	[23.67]		
			3		27.7577	13.4470	+ 75	+ 2.3	+ 1.0	40 42 25.21	— 6 1.79	— 56	+ 48	— 10	6	23.30	b	
			4		18.2070	21.7377	— 1	— .1	— .5	40 37 53.36	— 1 29.21	— 14	— 10	— 3	7	23.95	17.5	
			5		16.9117	25.1300	+ 73	+ 2.0	+ 1.8	40 32 54.26	+ 3 27.84	+ 33	+ 54	+ 7	7	23.11		
			6		24.8087	18.1883	+ 87	+ 1.7	+ .1	40 33 34.82	+ 2 47.50	+ 26	+ 27	+ 5	6	22.96		
			7		28.1637	11.9810	+ 10	— .2	+ 2.0	40 43 13.72	— 6 48.92	— 64	+ 23	— 12	7	[24.34]	17.9c	
			8		23.7047	17.4350	+ 32	+ .6	+ 1.0	40 33 44.34	+ 2 38.50	+ 25	+ 22	+ 5	6	23.42	16.6	
			9		24.3793	18.9517	+ 70	— .7	— .3	40 38 40.42	— 2 17.32	— 21	— 15	— 4	7	22.77		
			10		9.3317 ⁱⁱ	30.7380 ^{iv}	— 0	— 1.3	— 2.3	40 27 22.05	+ 9 0.89	+ 83	— 54	+ 20	9	23.52		
		II	1	D	17.1837	23.5290	+ 20	— 3.1	— 3.1	40 39 5.27	— 2 40.38	— 25	— 90	— 5	6	23.75	9.5b	
			2		23.2423	18.1080	+ 31	— .2	+ .2	40 38 32.72	— 2 9.81	— 20	— 5	— 3	6	22.69		
			3		20.7750	18.2593	— 11	— .7	— 1.4	40 35 19.79	+ 1 3.54	+ 10	— 29	+ 2	6	23.22	10.4	
			4		20.4573	18.4507	— 9	— .9	— .7	40 37 14.90	— 50.68	— 8	— 25	— 2	7	23.94	10.8b	
			5		18.6610	18.8947	— 4	— 1.0	— 1.9	40 36 29.64	— 5.89	— 1	— 40	0	9	23.43		
			6		31.6043 ^{iv}	8.7930 ⁱⁱ	+ 5	— .3	— .2	40 46 0.61	— 9 36.40	— 88	— 7	— 17	6	23.15	10.2	
			7		14.2550	25.8927	+ 7	+ 1.6	+ 3.0	40 41 16.99	— 4 54.07	— 46	+ 62	— 8	6	23.06	10.0	
			8		9.2690 ⁱⁱ	30.1943 ^{iv}	— 2	+ 2.5	+ 1.8	40 27 32.97	+ 8 48.73	+ 81	+ 63	+ 17	8	23.39		
Feb.	19	I	10		11.5430	27.6193	+ 15	+ .3	— .3	40 29 36.31	+ 6 46.25	+ 61	+ 1	+ 11	7	23.36	9.9	
			1	R	13.3837	28.7000	+ 139	+ .4	+ .1	40 42 50.88	— 6 27.36	— 56	+ 5	— 13	8	22.96	36	
			2		18.6097	22.7193	+ 23	— 1.4	— 1.7	40 34 39.36	+ 1 43.90	+ 15	— 44	+ 4	8	23.09		
Feb.	20	I	3	R	12.8043	27.1183	— 5	— 1.1	— 1.1	40 42 25.53	— 6 1.67	— 53	— 39	— 10	6	22.90	36.5	
			2		17.7277	21.8047	— 9	— 1.6	— .8	40 34 39.45	+ 1 42.99	+ 15	— 39	+ 4	8	22.32	33.9	
			3		12.0477	26.3877	— 97	— 1.1	0	40 42 25.63	— 6 2.09	— 53	— 17	— 10	6	22.80		
			4		22.8067	19.2490	+ 32	— 1.0	— 1.0	40 37 53.79	— 1 29.98	— 13	— 27	— 3	7	23.45	34.1	
Feb.	23	I	1	R	11.9477	27.3090	— 50	+ 1.5	+ 1.5	40 42 51.08	— 6 28.02	— 56	+ 41	— 13	8	22.86	22.5	
			2		17.6373	21.6820	— 12	+ 2.6	+ 1.7	40 34 39.60	+ 1 42.17	+ 15	+ 63	+ 4	8	22.67		
			3		13.3587	27.6937	+ 66	+ 1.3	+ .6	40 42 25.81	— 6 2.38	— 53	+ 30	— 10	6	23.16		
			4		23.2730	19.6704	+ 46	+ .8	+ .8	40 37 54.00	— 1 31.15	— 13	+ 23	— 3	7	22.99		
			5		25.2697	17.0783	+ 84	— 1.1	— 0	40 32 54.94	+ 3 27.19	+ 30	— 15	+ 7	7	22.42	22.3	
			6		16.7523	23.3610	+ 4	+ 2.1	+ 2.2	40 33 35.57	+ 2 47.00	+ 24	+ 62	+ 5	6	23.54	*	
			7		13.3100	29.5347	+ 201	— .4	+ .3	40 43 14.49	— 6 50.47	— 60	— 1	— 12	7	23.36	21.4	
			8		18.7200	24.9213	+ 98	+ 1.5	+ 1.7	40 33 45.21	+ 2 36.94	+ 23	+ 47	+ 5	6	22.96		
			9		18.0897	23.4643	+ 40	+ 1.9	+ 2.4	40 38 41.30	— 2 18.43	— 20	+ 61	— 4	7	23.31		
			10		32.1343 ^{iv}	10.7993 ⁱⁱ	+ 17	— .2	+ .2	40 27 23.05	+ 8 59.13	+ 77	— 0	+ 20	9	23.24	20.1	
		II	1	D	18.4400	24.8253	+ 91	+ .9	+ .7	40 39 5.44	— 2 41.57	— 24	+ 23	— 5	6	23.87	12.0	
			2		22.6247	17.4540	+ 2	— 3.6	— 3.1	40 38 32.84	— 2 10.66	— 19	+ 98	— 3	6	23.00		
			3		20.7480	18.2877	— 10	+ .4	+ 1.0	40 35 19.78	+ 1 2.14	+ 9	+ 21	+ 2	6	22.30	11.9	
			4		20.1477	18.0977	— 15	— .3	— .1	40 37 14.81	— 51.76	— 8	— 6	— 2	7	22.96	11.6	
			5		19.8987	20.1760	+ 1	+ 1.0	+ 1.3	40 36 29.47	— 7.01	— 1	+ 33	— 0	9	22.87		
			6		31.1100 ^{iv}	8.2883 ⁱⁱ	— 8	+ .9	— .5	40 46 0.42	— 9 36.63	— 82	+ 8	— 17	6	22.94	11.1	
			7		13.8853	25.5263	— 152	— .0	+ .8	40 41 16.66	— 4 53.76	— 43	+ 10	— 8	6	22.55		
Feb.	24	I	10		9.7060 ⁱⁱ	25.7673 ^{iv}	+ 78	+ .9	— .3	40 29 35.81	+ 6 46.03	+ 57	+ 10	+ 11	7	22.69	11.1	
			1	D	26.8507	11.4800	— 112	+ 2.6	+ 1.6	40 42 51.08	— 6 28.10	— 56	+ 62	— 13	8	22.99	10.3	
			2		22.2820	18.2153	+ 9	+ .8	+ .6	40 34 39.62	+ 1 42.78	+ 15	+ 20	+ 4	8	22.87		
			3		28.2880	13.9393	+ 140	+ 1.9	+ .5	40 42 25.83	— 6 2.91	— 53	+ 37	— 10	6	22.72		
			4		19.1947	22.7853	+ 31	+ .3	+ .0	40 37 54.03	— 1 30.80	— 13	+ 5	— 3	7	23.19	9.9	
			5		17.4353	25.6563	+ 112	+ .9	+ .6	40 32 54.98	+ 3 28.01	+ 30	+ 22	+ 7	7	23.65		
			6		23.3070	16.6973	0	+ .3	+ .8	40 33 35.62	+ 2 47.01	+ 24	+ 15	+ 5	6	23.13		
			7		28.9093	12.6203	+ 108	+ 3.8	+ 3.0	40 43 14.54	— 6 51.86	— 60	+ 1.00	— 12	7	23.03		

* Very unsteady.

OBSERVATIONS WITH THE ZENITH TELESCOPE.

93

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther- mom.
						A	B		Micrometer.	δ	l	r	Mer		
Feb. 24	I	8	22.1140	15.8947	-54	.5	.1	40 33 45.28	+2 37.01	+ 23	- 6	+ 5	6	40 36 22.57	9.0
		9	20.1203	14.6297	-127	.2	.3	40 38 41.37	-2 18.41	- 20	- 7	- 4	7	22.72	9.0
	II	10	9.7563 ⁱⁱ	31.0520 ^{iv}	+ 3	+1.4	+ .5	40 27 23.12	+8 58.10	+ 79	+ 29	+20	9	22.59	8.6
		1	22.1157	15.6620	-63	+2.0	+2.6	40 39 5.52	-2 42.91	- 24	+ 65	- 5	6	23.03	5.7
	II	2	17.3870	22.5543	- 1	+ .5	+ .4	40 38 32.91	-2 10.56	- 19	+ 13	- 3	6	22.32	
		3	18.6813	21.1650	- 2	+1.1	+ .6	40 35 19.85	+1 2.75	+ 9	+ 25	+ 2	6	23.02	4.8
	II	4	19.6900	21.7287	+ 12	.0	-1.0	40 37 14.86	- 51.54	- 8	- 13	- 2	7	23.16	
		5	19.8770	19.5920	- 2	+1.4	+ .2	40 36 29.51	- 7.20	- 1	+ 25	- 0	9	22.64	
	II	6	10.1007 ⁱⁱ	32.8920 ^{iv}	+ 37	-.8	+ .5	40 46 0.45	-9 35.97	- 84	- 6	-17	6	23.47	
		7	26.6740	15.0877	+ 90	+ .2	+ .2	40 41 16.68	-4 52.99	- 43	+ 5	- 8	6	23.29	5.6
	II	8	32.1777	11.2163	+ 14	+ .2	+3.4	40 27 32.61	+8 49.68	+ 77	+ 47	+17	8	23.78	
		10	27.9983 ^{iv}	11.8680 ⁱⁱ	+ 2	-3.4	-2.3	40 29 35.81	+6 47.58	+ 59	- 84	+11	7	23.32	5.6
	II	1	16.1750	22.5933	- 35	-.1	+ .8	40 39 5.67	-2 42.09	- 24	+ 9	- 5	6	23.44	18.5
		2	22.2737	17.1343	- 13	+2.4	+ .9	40 38 33.04	-2 9.83	- 19	+ 50	- 3	6	23.55	
Feb. 26	II	3	21.2810	18.7693	+ 1	-1.1	-1.3	40 35 19.95	+1 3.47	+ 9	- 34	+ 2	6	23.25	19.8
		4	20.4710	18.4177	- 10	-2.7	-2.3	40 37 14.95	- 51.86	- 8	- 73	- 2	7	23.33	19.3
	II	5	19.1880	19.4003	0	-1.9	-2.3	40 36 29.56	- 5.36	- 1	- 60	- 0	9	23.68	
		6	32.4810 ^{iv}	9.6937 ⁱⁱ	+ 27	+ .1	- .8	40 46 0.52	-9 35.85	- 88	- 9	-17	6	23.59	18.1
	II	7	13.1353	24.7290	-106	-.5	.0	40 41 16.72	-4 52.68	- 43	- 8	- 8	6	23.51	17.8
		8	9.4977 ⁱⁱ	30.4437 ^{iv}	0	+ .1	- .2	40 27 32.63	+8 49.26	+ 81	- 1	+17	8	22.94	
	II	10	12.9470 ⁱⁱ	29.0973 ^{iv}	- 34	-2.7	-3.9	40 29 35.81	+6 47.99	+ 63	- 93	+11	7	23.68	17.4
		1	9.9840	25.3170	-313	+1.3	+ .1	40 42 51.07	-6 26.64	- 56	+ 22	-13	8	24.04	35.0
	II	2	19.5523	23.6433	+ 57	-1.8	-2.0	40 34 39.64	+1 43.61	+ 15	- 54	+ 4	8	22.98	
		3	12.4127	26.7287	- 55	-1.9	- .2	40 42 25.88	-6 1.59	- 53	- 33	-10	6	23.39	
	II	4	22.0933	18.5230	+ 9	+ .9	- .1	40 37 54.09	-1 30.24	- 13	+ 13	- 3	7	23.89	34.4
		5	25.1000	16.8727	+ 71	-.2	+1.3	40 32 55.07	+3 28.06	+ 30	+ 13	+ 7	7	23.70	
	II	6	15.7503	22.3553	- 54	+2.1	+2.3	40 33 35.74	+2 46.76	+ 24	+ 63	+ 5	6	23.48	34.2
		7	12.9633	29.1693	+152	-1.3	-.9	40 43 14.66	-6 49.87	- 60	- 32	-12	7	23.82	34.2
Mar. 3	I	8	16.8280	23.0747	- 4	+ .8	+ .4	40 33 45.45	+2 37.83	+ 23	+ 18	+ 5	6	23.43	33.3*
		9	17.2663	22.7080	+ 2	-2.5	- .7	40 38 41.55	-2 17.50	- 20	- 49	- 4	7	23.39	
	I	10	30.9857 ^{iv}	9.6273 ⁱⁱ	+ 3	-1.9	-1.7	40 27 23.30	+8 59.68	+ 83	- 53	+20	9	23.57	32.4
		1	26.1917	10.8687	-196	-1.7	-.7	40 42 51.23	-6 26.68	- 56	- 36	-13	8	23.58	41.8
	I	2	22.5623	18.4893	+ 18	-.9	+ .7	40 34 39.83	+1 42.96	+ 15	- 5	+ 4	8	23.01	
		3	27.3787	13.0920	+ 30	-1.0	-1.9	40 42 26.11	-6 1.07	- 53	- 40	-10	6	24.07	
	I	4	17.9673	21.5317	- 7	-1.7	-2.0	40 37 54.34	-1 30.05	- 13	- 53	- 3	7	23.67	42.2
		5	16.2293	24.4457	- 26	+ .2	-.4	40 32 55.34	+3 27.54	+ 30	- 2	+ 7	7	23.30	
	I	6	23.5043	16.8787	+ 12	-1.6	-.7	40 33 36.05	+2 47.44	+ 24	- 35	+ 5	6	23.49	41.2
		7	28.2867	12.0503	+ 25	-1.6	-1.2	40 43 14.97	-6 50.32	- 60	- 41	-12	7	23.59	
	I	8	23.3337	17.0947	+ 12	-2.2	-1.2	40 33 45.82	+2 37.67	+ 23	- 50	+ 5	6	23.33	
		9	22.8400	17.3580	+ 4	-.0	-.5	40 38 41.93	-2 18.53	- 20	- 6	- 4	7	23.17	40.6
	II	10	9.3023 ⁱⁱ	30.6167 ^{iv}	- 1	-1.1	-1.6	40 27 23.65	+8 58.56	+ 83	- 38	+20	9	22.95	40.4
		1	23.4853	17.1203	+ 18	-2.7	-2.7	40 39 5.90	-2 40.87	- 24	- 77	- 5	6	24.03	33.0
Mar. 4	II	2	17.3407	22.4360	- 5	-1.0	-2.1	40 38 33.26	-2 8.73	- 19	- 43	- 3	6	23.94	31.8
		3	18.4700	20.9377	- 7	-1.9	-1.6	40 35 20.09	+1 2.34	+ 9	+ 51	+ 2	6	23.11	
	II	4	20.7110	22.7747	+ 31	-1.1	-1.6	40 37 15.03	- 52.22	- 8	- 38	- 2	7	22.40	
		5	20.6940	20.4500	+ 1	-2.0	-1.8	40 36 29.59	- 6.17	- 1	- 55	0	9	22.95	
	II	7	24.4587	12.8843	-133	-.3	-.8	40 41 16.67	-4 52.12	- 43	- 15	- 8	6	23.95	31.4
		8	31.2370 ^{iv}	10.2683 ⁱⁱ	+ 6	+ .1	+ .2	40 27 32.54	+8 49.84	+ 81	+ 4	+17	8	23.48	
	I	10	27.6473 ^{iv}	11.5350 ⁱⁱ	+ 14	-2.2	-2.1	40 29 35.66	+6 47.16	+ 63	- 62	+11	7	23.01	31.5
		1	13.1730	28.4967	+113	+ .2	-.5	40 42 51.28	-6 27.48	- 56	- 3	-13	8	23.16	42.6
	I	2	18.0963	22.1630	+ 5	-1.2	-.9	40 34 39.90	+1 42.77	+ 15	- 32	+ 4	8	22.62	
		3	12.1870	26.5373	- 79	+1.2	+ .3	40 42 26.19	-6 2.40	- 53	+ 22	-10	6	23.44	
	I	4	21.4913	17.8877	- 9	+1.1	-.1	40 37 54.42	-1 31.03	- 13	+ 16	- 3	7	23.46	43.1
		5	24.7823	16.5930	+ 48	.0	+ .9	40 32 55.43	+3 27.05	+ 30	+ 11	+ 7	7	23.03	42.8
	I	6	16.3543	22.9547	- 21	+2.3	+2.0	40 33 36.15	+2 46.72	+ 24	+ 63	+ 5	6	23.84	

* 20 s. late. Turned in azimuth; reduction to meridian—1'.37.

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther. mom.
						A	B		Micrometer.	δ	l	r	Mer		
Mar. 4	I	7 R	14.1423	30.3717	+319	-2.7	+ .4	40 43 15.08	-6 50.88	- 60	- 38	-12	7	40 36 23.17	42.4
		8	17.7000	23.9150	+ 43	+ .4	+ .8	40 33 45.94	+2 37.15	+ 23	+ 17	+ 5	6	23.60	
		9	16.3290	21.8087	- 45	- .5	- .1	40 38 42.05	-2 18.35	- 20	- 10	- 4	7	23.43	
		10	32.6753 ^{iv}	11.3727 ⁱⁱ	+ 23	+ .2	+ 1.5	40 27 23.78	+ 8 58.32	+ 83	+ 23	+ 20	9	23.45	
		II 1 D	17.2530	23.6493	+ 26	-1.8	-1.8	40 39 5.96	-2 41.68	- 24	- 52	- 5	6	23.53	
	II	2	22.1860	17.0473	- 17	-1.4	-1.3	40 38 33.32	-2 9.80	- 19	- 39	- 3	6	22.97	
		3	22.0443	19.5437	+ 16	- .9	- .8	40 35 20.14	+1 3.22	+ 9	- 25	+ 2	6	23.28	
		4	25.5347	23.4763	+ 81	- .4	+ .7	40 37 15.06	- 52.22	- 8	+ 2	- 2	7	22.83	
		5	19.6663	19.9250	- 1	+ .5	- .2	40 36 29.61	- 6.54	- 1	+ 5	0	9	23.20	
		6	32.0417 ^{iv}	9.2307 ⁱⁱ	+ 15	+1.0	+1.2	40 46 0.57	-9 36.42	- 88	+ 31	-17	6	23.47	
Mar. 7	I	7	14.4090	26.0093	+ 17	-1.3	-1.2	40 41 16.68	-4 53.15	- 43	- 36	- 8	6	22.72	
		8	10.3220 ⁱⁱ	31.3090 ^{iv}	+ 5	- .6	- .1	40 27 32.53	+8 50.30	+ 81	- 11	+17	8	23.78	
		10	13.4640 ⁱⁱ	29.6180 ^{iv}	- 51	-3.1	-4.2	40 29 35.64	+6 48.04	+ 63	-1.03	+11	7	23.46	
		1	27.2583	11.9153	- 55	+ .3	-1.2	40 42 51.40	-6 27.54	- 56	- 10	-13	8	23.15	
		2	22.8897	18.7977	+ 30	-1.1	-3.1	40 34 40.05	+1 43.47	+ 15	- 57	+ 4	8	23.22	
	II	3	27.7603	13.4370	+ 75	.0	- .3	40 42 26.35	-6 2.10	- 53	- 4	-10	6	23.64	
		4	17.7070	21.2863	- 16	.0	-1.4	40 37 54.62	-1 30.40	- 13	- 18	- 3	7	23.95	
		5	15.6190	23.8547	- 20	- .6	- .3	40 32 55.66	+3 28.05	+ 30	- 13	+ 7	7	24.02	
		6	23.3730	16.7770	+ 4	+ .8	+ .3	40 33 36.41	+2 46.68	+ 24	+ 17	+ 5	6	23.61	
		7	28.5187	12.2763	+ 56	-1.7	- .9	40 43 15.36	-6 50.55	- 60	- 38	-12	7	23.78	
Mar. 8	I	8	23.3743	17.1300	+ 14	-2.5	-1.8	40 33 46.27	+2 37.81	+ 23	- 63	+ 5	6	23.79	
		9	22.9567	17.4810	+ 10	-2.1	-2.3	40 38 42.40	-2 18.38	- 20	- 63	- 4	7	23.22	
		10	9.6600 ⁱⁱ	30.9450 ^{iv}	+ 3	+ .3	+ .2	40 27 24.12	+8 57.83	+ 83	+ 7	+20	9	23.14	
		1	13.3980	28.7070	+140	-1.6	-1.8	40 42 51.40	-6 27.18	- 56	- 48	-13	8	23.13	
		2	19.2647	23.3577	+ 47	-2.7	-2.5	40 34 40.06	+1 43.54	+ 15	- 75	+ 4	8	23.12	
	II	3	12.0620	26.3947	- 96	- .3	-1.2	40 42 26.38	-6 1.91	- 53	- 21	-10	6	23.69	
		5	24.3350	16.1427	+ 18	+ .2	+ .5	40 32 55.70	+3 27.05	+ 30	+ 10	+ 7	7	23.29	
		6	17.0317	23.6003	+ 20	- .1	+ .5	40 33 36.47	+2 46.02	+ 24	+ 5	+ 5	6	22.89	
		8	19.9047	26.0780	+171	- .2	.0	40 33 46.34	+2 36.39	+ 23	- 3	+ 5	6	23.04	
		10	31.1900 ^{iv}	9.9017 ⁱⁱ	+ 5	-1.0	+ .1	40 27 24.20	+8 57.92	+ 83	- 14	+20	9	23.10	
Mar. 12	I	1 R	23.1260	16.6830	- 5	- .8	- .9	40 39 6.45	-2 42.79	- 24	- 25	- 5	6	23.18	
		2	18.3410	23.4847	+ 41	-1.9	-2.1	40 38 33.78	-2 10.07	- 19	- 57	- 3	6	22.98	
		3	19.2300	21.7207	+ 10	- .2	- .6	40 35 20.54	+1 2.96	+ 9	- 10	+ 2	6	23.57	
		1	27.3263	11.9827	- 45	+ .4	.0	40 42 51.29	-6 27.58	- 56	+ 6	-13	8	23.16	
		2	22.1663	18.0783	+ 2	- .6	-2.2	40 34 40.00	+1 43.30	+ 15	- 38	+ 4	8	23.19	
	II	3	27.5810	13.2363	+ 53	+1.6	+1.0	40 42 26.34	-6 2.59	- 53	+ 39	-10	6	23.57	
		4	16.8717	20.4793	- 41	+ .5	- .4	40 37 54.65	-1 31.05	- 13	+ 3	- 3	7	23.54	
		5	15.5393	23.7237	- 25	+1.5	+ .5	40 32 55.73	+3 26.74	+ 30	+ 31	+ 7	7	23.22	
		6	23.3553	16.7413	+ 3	-1.5	- .9	40 33 36.53	+2 47.13	+ 24	- 35	+ 5	6	23.66	
		7	28.6633	12.3950	+ 75	- .6	+ .3	40 43 15.51	-6 51.25	- 60	- 5	-12	7	23.56	
Mar. 13	I	8	23.2530	17.0620	+ 9	- .5	- .4	40 33 46.51	+2 36.45	+ 23	- 13	+ 5	6	23.17	
		9	23.4223	17.9027	+ 33	+ .8	.0	40 38 42.66	-2 19.55	- 20	+ 13	- 4	7	23.07	
		10	9.0313 ⁱⁱ	30.3100 ^{iv}	- 3	+ .6	+1.6	40 27 24.39	+8 57.65	+ 83	+ 30	+20	9	23.46	
		6 R	8.8807 ⁱⁱ	31.7110 ^{iv}	+ 7	- .8	- .1	40 46 1.37	-9 36.89	- 88	- 14	-17	6	23.35	
		7	25.9220	14.2980	+ 10	+ .6	+ .7	40 41 17.34	-4 53.74	- 43	- 18	- 8	6	22.97	
	II	8	32.0060 ^{iv}	11.0540 ⁱⁱ	+ 12	- .3	- .8	40 27 33.07	+8 49.44	+ 81	- 15	+17	8	23.42	
		9	22.7030	19.1597	+ 29	- .1	-1.5	40 34 53.73	+1 29.60	+ 13	- 21	+ 3	6	23.34	
		10	27.6543	11.5673	+ 14	- .7	- .9	40 29 36.12	+6 46.52	+ 63	- 22	+11	7	23.23	
		1	13.0573	28.8773	+ 97	- .2	-1.2	40 42 51.25	-6 27.34	- 56	- 18	-13	8	23.12	
		2	18.7307	22.8137	+ 26	-1.3	-1.9	40 34 39.99	+1 43.23	+ 15	- 45	+ 4	8	23.04	
Mar. 14	I	3	12.8477	27.1957	+ 3	+ .3	+ .3	40 42 26.34	-6 2.55	- 53	+ 10	-10	6	23.32	
		4	22.6177	19.0087	+ 26	+1.1	+1.2	40 37 54.66	-1 31.26	- 13	+ 33	- 3	7	23.64	
		5	24.7870	16.6140	+ 49	- .3	+ .7	40 32 55.75	+3 26.64	+ 30	+ 4	+ 7	7	22.87	
		6	17.1053	23.6670	+ 23	+1.3	+1.3	40 33 36.58	+2 45.86	+ 24	+ 37	+ 5	6	23.16	
		7	13.2737	29.5447	+196	+ .7	+1.5	40 43 15.55	-6 51.62	- 60	+ 30	-12	7	23.58	

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.	
						A	B		Micrometer.	δ	l	r	Mer			
Mar. 14	I	8	R	17.9483	24.1393	+ 57	— .6	— .2	40 33 46.58	+2 36.58	+ 23	— 12	+ 5	6	40 36 23.38	○
		9		17.4697	22.9923	+ 10	+ .2	+ .1	40 38 42.74	—2 19.57	— 20	+ 4	— 4	7	23.04	
		10		32.2447 ^{iv}	10.9657 ⁱⁱ	+ 18	— .1	+ .6	40 27 24.47	+8 57.71	+ 83	+ 6	+20	9	23.36	40.6
	II	1	D	16.1143	22.5567	— 37	—1.4	—3.2	40 39 7.19	—2 42.69	— 24	— 63	— 5	6	23 64	31.8
		2		23.1517	17.9513	+ 26	+ .7	— .2	40 38 34.50	—2 11.47	— 19	+ 8	— 3	6	22.95	
		3		20.9760	18.5267	— 6	—1.3	— .2	40 35 21.51	+1 1.87	+ 9	— 23	+ 2	6	23.32	
		4		20.2793	18.1707	— 14	+ .7	— .2	40 37 15.98	— 53.24	— 8	+ 8	— 2	7	22.79	31.8
		5		19.7080	20.0140	— 1	+1.4	+1.2	40 36 30.41	— 7.73	— 1	+ 38	— 0	9	23.14	
		6		31.2250 ^{iv}	8.3673 ⁱⁱ	— 5	+1.9	+1.1	40 46 1.44	—9 37.55	— 88	+ 44	—17	6	23.34	31.5
		7		14.8403	26.4743	+ 69	—1.0	— .9	40 41 17.40	—4 54.14	— 43	— 27	— 8	6	22.54	
		8		8.0649 ⁱⁱ	29.0070 ^{iv}	— 12	+ .6	+1.3	40 27 33.12	+8 49.13	+ 81	+ 26	+17	8	23.57	
		9		17.8033	21.3407	— 11	+ .6	+ .1	40 34 53.78	+1 29.35	+ 13	+ 11	+ 3	6	23.46	
Mar. 16	I	10		12.0830 ⁱⁱ	28.1620 ^{iv}	+ 17	+1.2	— .3	40 29 36.17	+6 46.32	+ 63	+ 15	+11	7	23.45	31.4
		3	D	28.0587	13.7120	+110	0	— .1	40 42 26.39	—6 2.78	— 53	— 2	—10	6	23.02	51.4
		4		16.9347	20.5867	— 39	+1.2	+1.8	40 37 54.73	—1 32.18	— 13	+ 42	— 3	7	22.88	50.6
		5		16.9163	24.5183	+ 48	+1.7	+1.5	40 32 55.83	+3 27.37	+ 30	+ 46	+ 7	7	24.10	
		6		23.6873	17.1217	+ 25	+ .1	+ .1	40 33 36.67	+2 45.96	+ 24	+ 3	+ 5	6	23.01	
		7		28.1300	11.8323	— 3	— .2	+4.1	40 43 15.65	—6 51.80	— 60	+ 50	—12	7	23.70	50.4c
		8		23.1417	16.9983	+ 4	+1.3	+1.1	40 33 46.71	+2 35.24	+ 23	+ 35	+ 5	6	22.64	
		9		23.1937	17.6530	+ 20	+1.2	+1.3	40 38 42.88	—2 20.05	— 20	+ 35	— 4	7	23.01	
		10		8.7160 ⁱⁱ	29.9680 ^{iv}	— 8	0	+ .5	40 27 24.59	+8 56.97	+ 83	+ 7	+20	9	22.75	50.0
	II	1	R	24.6417	18.2297	+ 81	—5.0	—6.0	40 39 7.38	—2 42.22	— 24	—1.57	— 5	6	23.36	39.2
		2		17.4323	22.5893	0	—1.8	—1.8	40 38 34.70	—2 10.31	— 19	— 52	— 3	6	23.71	
		3		18.8627	21.2823	+ 2	+ .5	+ .6	40 35 21.36	+1 1.14	+ 9	+ 15	+ 2	6	22.82	40.
		4		19.3127	21.4197	+ 6	+ .3	+ .1	40 37 16.12	— 53.25	— 8	+ 7	— 2	7	22.91	
		5		20.6257	20.3453	+ 1	—1.7	—1.9	40 36 30.52	— 7.09	— 1	— 51	— 0	9	23.00	
		6		7.8610 ⁱⁱ	30.7110 ^{iv}	— 17	—1.3	—1.6	40 46 1.56	—9 37.32	— 92	— 41	—17	6	22.80	
		7		25.1797	13.5477	— 64	— .9	— 7	40 41 17.51	—4 53.75	— 43	— 23	— 8	6	23.08	39.6
		8		29.1447 ^{iv}	8.2067 ⁱⁱ	— 11	+ .3	0	40 27 33.19	+8 49.03	+ 85	+ 5	+17	8	23.37	
		9		23.5340	19.9957	+ 55	— .5	+ .3	40 34 53.86	+1 29.54	+ 13	— 4	+ 3	6	23.58	
Mar. 17	I	10		28.8920 ^{iv}	12.8117 ⁱⁱ	— 30	— .5	—1.9	40 29 36.24	+6 46.23	+ 67	— 33	+12	7	23.00	38.9
		3	R	12.8450	27.1837	+ 8	— .7	+ .1	40 42 26.44	—6 2.33	— 53	— 9	—10	6	23.45	52.7
		4		22.3157	18.7087	+ 16	—1.2	— .2	40 37 54.78	—1 31.18	— 13	— 21	— 3	7	23.30	
		5		23.0040	14.7873	— 79	—1.7	— .2	40 32 55.89	+3 27.42	+ 30	— 30	+ 7	7	23.45	
		6		17.2253	23.8267	+ 31	—2.7	—2.0	40 33 36.74	+2 46.89	+ 24	— 68	+ 5	6	23.30	51.4
		7		12.1883	28.4677	+ 48	+ .3	— .9	40 43 15.72	—6 51.46	— 60	— 7	—12	7	23.54	51.4
		8		17.0213	23.2087	+ 6	— .3	— .5	40 33 46.80	+2 36.36	+ 23	— 12	+ 5	6	23.38	
		9		17.5577	23.0807	+ 2	— .7	—1.5	40 38 42.97	—2 19.56	— 20	— 31	— 4	7	22.93	
		10		31.3827 ^{iv}	10.1000 ⁱⁱ	+ 9	—1.6	— .6	40 27 24.79	+8 57.79	+ 92	— 33	+20	9	23.46	50.2
	II	1	D	17.0610	23.5513	+ 18	— .1	+ .3	40 39 7.49	—2 44.04	— 24	+ 2	— 5	6	23.24	40.8
Mar. 18	I	2		22.2950	17.1033	— 13	0	—1.2	40 38 34.80	—2 11.15	— 19	— 15	— 3	6	23.34	
		3		21.6007	19.1277	+ 8	—2.0	—1.1	40 35 21.47	+1 2.51	+ 9	— 46	+ 2	6	23.69	41.2d
		4	R	12.5027	26.8743	— 40	+1.3	+ .8	40 42 26.48	—6 3.03	— 53	+ 31	—10	6	23.19	58.3a
		5		22.9040	19.2667	+ 34	+1.0	0	40 37 54.83	—1 31.99	— 13	+ 16	— 3	7	22.91	
		6		23.4573	15.2570	— 46	0	0	40 32 55.95	+3 27.09	+ 30	0	+ 7	7	23.48	58.
		7		16.7113	23.2780	— 1	— .3	+1.0	40 33 36.81	+2 45.92	+ 24	+ 8	+ 5	6	23.16	
		8		11.6183	27.9270	— 33	+1.7	+1.6	40 43 15.80	—6 52.00	— 60	+ 48	—12	7	23.63	56.9
		9		17.3870	23.5400	+ 26	+2.5	+1.6	40 33 46.89	+2 35.54	+ 23	+ 60	+ 5	6	23.37	56.2
		10		17.7930	23.3277	+ 27	+ .4	+1.7	40 38 43.06	—2 19.92	— 20	+ 28	— 4	7	23.25	
Mar. 19	II	1	R	30.7977 ^{iv}	9.5630 ⁱⁱ	+ 1	+1.7	+2.1	40 27 24.78	+8 56.55	+ 92	+ 54	+20	9	23.08	56.6
		2		24.9827	18.5033	+ 98	—1.1	—1.0	40 39 7.78	—2 43.97	— 23	— 31	— 5	6	23.28	46.9
		3		17.7423	22.9773	+ 15	+2.2	+2.0	40 38 35.08	—2 12.31	— 19	+ 60	— 3	6	23.21	
		4		18.5947	21.0397	— 4	+1.7	+ .9	40 35 21.72	+1 1.77	+ 8	+ 39	+ 2	6	24.04	44.9
		5		20.8263	18.6863	— 5	— .3	+ .1	40 37 16.42	— 54.06	— 8	— 3	— 2	7	22.30	
		6		19.1287	19.4450	— 1	+1.1	+ .1	40 36 30.78	— 7.99	— 2	+ 19	0	9	23.05	

1891.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther- mom.
						A	B		Micrometer.	δ	l	r	Mer		
Mar.	19	II 6 R	30.7133 ^{iv}	7.8133 ⁱⁱ	-18	+1.1	-.1	40 46 1.85	-9 38.58	-92	+16	-17	6	40 36 22.40	45.6
			13.6557	25.2887	-53	-1.6	-1.4	40 41 18.16	-4 53.80	-41	-44	-8	6	23.49	
			8.3613 ⁱⁱ	29.8097 ^{iv}	-10	-.8	-.1	40 27 33.38	+8 49.29	+84	-14	+17	8	23.62	
Apl.	10	II 1 D	11.3377 ⁱⁱ	27.3593 ^{iv}	+23	+1.3	+1.1	40 29 36.42	+6 44.89	+67	+22	+12	7	[22.39]	45.4d
	6		17.0257	23.6460	+21	-.1	-.7	40 39 11.80	-2 47.33	-23	-10	-5	6	23.65	35.9
Apl.	9	II 2	24.4007	19.0670	+82	+3.3	+1.7	40 38 38.60	-2 14.98	-19	+62	-3	6	[24.08]	c
			17.3743	24.0197	+40	-1.3	-1.0	40 39 11.95	-2 48.01	-23	-34	-5	6	23.88	37.
			23.6810	18.3187	+47	+1.3	+1.5	40 38 39.26	-2 15.61	-19	+42	-3	6	23.91	
			21.2437	18.9810	+3	-1.6	-1.4	40 35 24.77	+ 57.18	+ 8	-43	+2	6	[21.68]	36.7
			21.2707	18.9983	+4	-.9	-2.0	40 37 20.12	- 57.43	- 8	-40	-2	7	22.26	
			19.8137	20.2530	0	-.4	-.9	40 36 34.23	- 11.10	- 2	-18	0	9	23.02	
			32.2450 ^{iv}	9.2270 ⁱⁱ	+19	+1.4	+1.4	40 46 5.65	-9 41.66	-92	+27	-17	6	23.23	36.6
			14.6820	26.5080	+61	-.2	+1.8	40 41 21.35	-4 58.97	-41	+7	-8	6	22.02	
			8.6510 ⁱⁱ	29.4203 ^{iv}	-7	+2.2	+2.8	40 27 36.60	+8 44.77	+84	+71	+17	8	23.17	
			18.1540	21.5463	-4	-1.6	-2.0	40 34 57.39	+1 25.71	+11	-51	+3	6	22.79	
Apl.	13	II 1 R	12.7983 ⁱⁱ	28.7287 ^{iv}	-27	+1.2	+1.7	40 29 39.75	+6 42.45	+67	+28	+12	7	23.34	36.1
			23.8887	17.2000	+32	+1.0	+1.8	40 39 12.69	-2 49.09	-23	-26	-5	6	23.64	42.1
			17.8200	23.2037	+24	0	-.2	40 38 40.01	-2 16.09	-19	-2	-3	6	23.74	41.9
			20.4647	22.6927	+30	+1.3	+1.6	40 35 26.51	+ 56.37	+ 8	+28	+2	6	23.32	40.2
			20.5203	22.7890	+32	-.5	-1.5	40 37 20.80	- 57.41	- 8	-27	-2	7	23.09	
			21.2203	20.7523	+4	+1.5	-.2	40 36 34.88	- 11.84	- 2	+6	-0	9	23.17	
			8.8127 ⁱⁱ	31.8287 ^{iv}	+8	-2.0	-.9	40 46 6.38	-9 41.58	-92	-43	-17	6	23.34	
			26.4750	14.7010	+61	-1.0	-2.0	40 41 22.06	-4 57.65	-41	-41	-8	6	23.57	40.8
			31.7503 ^{iv}	10.9600 ⁱⁱ	+9	-1.3	-.4	40 27 37.21	+8 45.34	+84	-26	+17	8	23.38	
			23.0857	19.6927	+41	-2.3	-2.0	40 34 58.07	+1 25.84	+11	-62	+3	6	23.49	
Apl.	14	II 1 D	28.3920 ^{iv}	12.4817 ⁱⁱ	-16	-.7	0	40 29 40.44	+6 41.98	+67	-11	+11	7	23.16	40.0
			16.2990	22.9970	-22	-.2	0	40 39 12.89	-2 49.19	-23	-3	-5	6	23.45	43.3
			22.6800	17.2853	-0	-1.3	-2.0	40 38 40.22	-2 16.31	-19	-46	-3	6	23.29	
			20.1590	17.9130	-18	-2.3	-1.9	40 35 26.72	+ 56.71	+ 8	-61	+2	6	22.98	43.4
			20.4247	18.1323	-13	-1.0	-.5	40 37 20.98	- 57.89	- 8	-22	-2	7	22.84	42.8
			18.4033	18.8663	-6	-1.4	-.9	40 36 35.04	- 11.68	- 2	-34	0	9	23.09	43.4
			29.8033 ^{iv}	6.8037 ⁱⁱ	-44	-.2	-2.0	40 46 6.57	-9 41.03	-92	-23	-17	6	24.23	
			13.4940	25.3260	-70	-1.9	-1.0	40 41 22.24	-4 58.81	-41	-43	-8	6	22.57	42.9
			8.1900 ⁱⁱ	28.9643 ^{iv}	-9	-1.5	-.9	40 27 37.38	+8 44.89	+84	-35	+17	8	23.01	
			16.9380	20.3047	-41	+1.4	+1.2	40 34 58.25	+1 24.96	+11	+38	+3	6	23.79	
Apl.	15	II 1 R	11.9267 ⁱⁱ	27.8267 ^{iv}	+5	-.6	+1.1	40 29 40.62	+6 41.77	+67	-8	+11	7	23.16	42.4
			22.7383	16.0067	-37	-.1	+1.1	40 39 13.13	-2 50.00	-23	-0	-5	6	22.91	46.7
			17.4240	22.8357	-5	-.2	-.9	40 38 40.44	-2 16.73	-19	-14	-3	6	23.41	45.3
			18.5767	20.7847	-6	+1.6	+1.4	40 35 26.93	+ 55.78	+ 8	+30	+2	6	23.17	
			18.1947	20.5027	-12	-1.4	-.8	40 37 21.08	- 58.29	- 8	-33	-2	7	22.43	
			22.2370	21.7820	+8	-2.3	-2.2	40 36 35.23	- 11.52	- 2	-65	-0	9	23.13	
			9.0410 ⁱⁱ	32.0737 ^{iv}	+15	-.9	-.6	40 46 6.78	-9 42.02	-92	-22	-17	6	23.51	45.3*
			26.4163	14.6070	+52	-.6	-1.7	40 41 22.45	-4 58.52	-41	-31	-8	6	23.19	45.1
			32.0403 ^{iv}	11.2750 ⁱⁱ	+10	-2.0	-2.0	40 27 37.57	+8 44.71	+84	-57	+17	8	22.80	45.5
			22.0397	19.6700	+17	-2.3	-2.0	40 34 58.44	+1 25.19	+11	-62	+3	6	23.21	
Apl.	16	II 1 D	27.1493 ^{iv}	11.2710 ⁱⁱ	+28	+1.1	+1.0	40 29 40.82	+6 41.28	+54	+30	+11	7	23.12	44.6
			17.3667	24.1070	+43	+2.1	+2.0	40 39 13.37	-2 50.42	-23	+59	-5	6	23.32	51.3
Apl.	22	II 1 D	21.0187	18.7927	-3	-1.7	-1.6	40 35 27.17	+ 56.24	+ 8	-47	+2	6	23.10	
			16.1913	22.9783	-25	+1.4	-.4	40 39 14.91	-2 51.43	-23	+1	-5	6	23.27	48.5
			22.0627	16.5613	-35	+1.4	+1.6	40 38 42.27	-2 18.92	-19	+30	-3	6	23.49	
			21.3607	19.2300	+6	+1.6	+1.3	40 35 28.75	+ 53.85	+ 8	+13	+2	6	22.89	48.2
			21.0953	18.7180	-3	-.3	-.4	40 37 22.89	-1 0.06	- 8	-10	-2	7	22.70	47.8
			19.1037	19.6577	-2	+1.2	+1.1	40 36 36.88	- 13.99	- 2	+4	0	9	23.00	
			32.5337 ^{iv}	9.4347 ⁱⁱ	+26	+1.1	-.1	40 46 8.60	-9 43.72	-79	-0	-17	6	23.98	
			14.0163	25.9127	-3	-.9	-.7	40 41 24.24	-5 0.59	-41	-24	-8	6	22.98	47.8

* Light poor. !

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther. mom.
						A	B		Micrometer.	δ	l	r	Mer		
Apl. 22	II 8	D	7.8953 ⁱⁱ	28.6263 ^{iv}	-10	-.9	-.8	40 27 39.18	+8 43.80	+ 84	- 25	+17	8	40 36 23.82	○
	9		17.6487	20.9367	-21	-.3	-1.2	40 35 0.18	+1 23.03	+ 11	- 20	+ 3	6	23.21	
Apl. 24	II 10		12.1780 ⁱⁱ	28.0073 ^{iv}	-4	-.8	-.6	40 29 42.58	+6 39.96	+ 67	- 20	+12	7	23.20	47.4
	1	R	22.3197	15.4890	-66	+.9	+.2	40 39 15.34	-2 52.43	- 23	+ 17	- 5	6	23.86	48.0
	2		18.6303	24.1213	+66	-1.8	-1.7	40 38 42.72	-2 18.91	- 19	- 51	- 3	6	23.14	
	3		18.8923	21.0030	+ 1	+1.2	+1.4	40 35 29.22	+ 53.33	+ 8	+ 37	+ 2	6	23.08	47.6
	4		19.5477	21.9553	+14	+.7	+1.2	40 37 23.32	-1 0.87	- 8	+ 26	- 2	7	22.68	
	5		20.4947	19.9217	+ 2	+.3	+.3	40 36 37.29	-14.48	- 2	+ 9	- 0	9	22.97	
	6		8.9780 ⁱⁱ	32.1273 ^{iv}	+16	-.6	+.2	40 46 9.07	-9 44.97	- 92	- 07	-17	6	23.00	
	7		27.7393	15.8523	+180	-.2	-.6	40 41 24.70	-5 0.81	- 41	- 11	- 8	6	23.35	46.9
	8		30.9647 ^{iv}	10.2933 ⁱⁱ	+ 3	-1.5	.0	40 27 39.64	+8 42.32	+ 84	- 24	+17	8	22.81	
	9		22.9960	19.7480	+38	-.8	+.7	40 35 0.65	+1 22.17	+ 11	- 4	+ 3	6	22.98	
Apl. 25	II 10		26.6910 ^{iv}	10.8980 ⁱⁱ	+45	-.3	-.0	40 29 43.05	+6 39.16	+ 67	- 5	+11	7	23.01	47.3
	1	D	17.6377	24.4247	+62	-1.1	-.5	40 39 15.55	-2 51.65	- 23	- 24	- 5	6	23.44	51.4
	2		22.7720	17.2567	+ 1	+.3	.0	40 38 42.98	-2 19.36	- 19	+ 5	- 3	6	23.51	
	3		20.6180	18.5010	- 8	-1.8	-1.2	40 35 29.44	+ 53.47	+ 8	- 44	+ 2	6	22.63	51.0
	4		21.8527	18.9620	+ 4	-1.5	-2.2	40 37 23.51	-1 0.42	- 8	- 52	- 2	7	22.54	
	5		19.9047	20.4987	+ 2	-.7	-.3	40 36 37.48	-15.01	- 2	- 15	- 0	9	22.39	
	6		32.0287 ^{iv}	8.8947 ⁱⁱ	+12	+.6	-.7	40 46 9.28	-9 44.57	- 92	0	-17	6	23.68	49.6
	7		13.8960	25.8657	-12	+1.6	+.4	40 41 24.93	-5 2.42	- 41	+ 31	- 8	6	22.39	50.1
	8		8.1167 ⁱⁱ	28.8037 ^{iv}	- 8	+.8	-.2	40 27 39.83	+8 42.69	+ 84	+ 10	+17	8	23.71	
	9		19.3397	22.5777	+27	+2.2	+1.1	40 35 0.86	+1 21.88	+ 11	+ 49	+ 3	6	23.43	
	10		12.5787 ⁱⁱ	28.3727 ^{iv}	-18	+1.2	-.5	40 29 43.28	+6 39.03	+ 67	+ 12	+11	7	23.28	49.6
Apl. 26	II 1	R	23.1627	16.3257	-16	+2.7	+2.2	40 39 15.75	-2 52.71	- 23	+ 71	- 5	6	23.53	56.3
	2		17.0677	22.6257	- 5	+.9	+1.9	40 38 43.14	-2 20.42	- 19	+ 39	- 3	6	22.95	
	3		18.3563	20.4947	-10	-1.7	-.9	40 35 29.65	+ 54.01	+ 8	- 37	+ 2	6	23.45	56.2
	4		19.3673	21.7727	+11	-.7	+.2	40 37 23.71	-1 0.81	- 8	- 8	- 2	7	22.79	55.9
	5		20.2477	19.6683	0	.0	-.1	40 36 37.67	-14.64	- 2	- 2	- 0	9	23.08	
	6		9.0603 ⁱⁱ	32.2220 ^{iv}	+18	-.4	+.1	40 46 9.49	-9 45.29	- 92	- 5	-17	6	23.12	
	7		26.5730	14.6500	+63	-.1	-.7	40 41 25.13	-5 1.42	- 41	- 11	- 8	6	23.17	55.0
	8		31.3597 ^{iv}	10.6767 ⁱⁱ	+ 6	-.5	.0	40 27 40.02	+8 42.62	+ 84	- 8	+17	8	23.65	
	9		21.8613	18.5927	+ 6	-2.8	-1.4	40 35 1.06	+1 22.60	+ 11	- 63	+ 3	6	23.23	
	10		28.2007 ^{iv}	12.4113 ⁱⁱ	-12	-.5	-.5	40 29 43.48	+6 38.93	+ 67	- 15	+11	7	23.11	54.9
Apl. 30	II 1	D	16.6610	23.5033	+ 5	+.1	-.7	40 39 16.68	-2 52.90	- 23	- 7	- 5	6	23.49	55.6
	2		21.4757	15.9133	-64	-1.1	-.2	40 38 44.00	-2 20.39	- 19	+ 20	- 3	6	23.65	
	3		20.3073	18.2343	-13	-1.4	-1.0	40 35 30.61	+ 52.35	+ 8	- 36	+ 2	6	22.76	55.4
	4		19.2743	16.8100	-42	+.5	-.2	40 37 24.60	-1 2.16	- 8	+ 5	- 2	7	22.46	
	5		20.4890	21.0930	+ 3	-2.0	-.4	40 36 38.52	-15.27	- 2	- 37	- 0	9	22.95	55.4
	6		32.2800 ^{iv}	9.1050 ⁱⁱ	+19	+.8	-.6	40 46 10.45	-9 45.62	- 96	+ 5	-17	6	23.81	55.2
	7		15.3400	27.3027	+137	-1.3	-.0	40 41 26.08	-5 2.61	- 41	- 20	- 9	6	22.83	54.4
	8		10.5163 ⁱⁱ	31.1687 ^{iv}	+ 4	-2.2	-0.6	40 27 40.87	+8 41.85	+ 88	- 43	+17	8	23.42	
	9		19.3413	22.5773	+27	-.8	-1.7	40 35 1.98	+1 21.83	+ 11	- 33	+ 3	6	23.68	
	10		13.4317 ⁱⁱ	29.1860 ^{iv}	-40	.0	-.6	40 29 45.42	+6 37.97	+ 71	- 7	+12	7	[24.22]	54.8*
May 8	II 1	R	23.3170	16.3957	- 9	-.6	-.3	40 39 18.67	-2 54.86	- 22	- 14	- 5	6	23.46	63.6
	2		17.1610	22.8323	- 0	+.4	+.5	40 38 46.13	-2 23.30	- 18	+ 13	- 4	6	22.80	
	3		18.2903	20.2837	-12	-.2	-.7	40 35 32.70	+ 50.34	+ 6	- 12	+ 2	6	23.06	62.3
	4		19.5590	22.0697	+17	-1.9	-1.0	40 37 26.58	-1 3.48	- 8	- 44	- 2	7	22.63	
	5		22.6500	21.9620	+15	-.7	-.9	40 36 40.45	-17.42	- 3	- 22	- 1	9	22.86	60.6
	6		8.4567 ⁱⁱ	31.7183 ^{iv}	+ 3	-.3	-1.5	40 46 12.61	-9 47.77	- 91	- 24	-17	6	23.58	
	7		26.8697	14.8150	+88	-1.3	-1.7	40 41 28.27	-5 4.82	- 38	- 42	- 9	6	22.62	
	8		30.9470 ^{iv}	10.3823 ⁱⁱ	+ 2	-1.5	-.6	40 27 42.89	+8 39.63	+ 81	- 31	+17	8	23.27	59.2
	9		22.4277	19.2827	+23	-1.2	-1.8	40 35 4.16	+1 19.52	+ 9	- 41	+ 3	6	23.45	59.6
	10		27.4007 ^{iv}	11.7337 ⁱⁱ	+17	-2.1	-2.0	40 29 46.66	+6 35.91	+ 66	- 57	+12	7	22.35	59.3
	1	R	30.1853	14.5117	+319	+.3	+1.1	40 43 0.89	-6 36.84	- 49	+ 19	-14	10	23.21	59.4
	2		9.5300 ⁱⁱ	33.7297 ^{iv}	+59	-.6	-.5	40 46 36.22	-10 11.62	- 93	- 16	-23	11	23.39	

* Mistake in micrometer reading.

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther. mom.
						A	B		Micrometer.	δ	l	r	Mer		
May 8	III 3	R	7.4240 ^{II}	32.8270 ^{IV}	+ 5	+3.4	+1.6	40 25 39.75	+10 41.89	+ 96	+ 74	+18	6	40 36 23.58	°
			8.2260 ^{II}	33.4407 ^{IV}	+ 39	— .8	— .8	40 25 45.23	+10 37.21	+ 95	— 15	+19	6	23.49	
			26.9493	15.1167	+107	+ .3	+ .2	40 31 22.94	+ 4 59.25	+ 37	+ 7	+10	7	22.80	59.8
			19.0100	22.3030	+ 20	—2.3	— .9	40 37 46.62	— 1 23.26	— 11	— 48	— 3	6	22.80	
			21.0007	19.7547	+ 3	+ .2	—1.1	40 36 54.43	— 31.49	— 4	— 11	— 1	6	22.84	59.7
May 9	II 1	D	17.2300	24.2283	+ 45	+ .6	—1.1	40 33 26.19	+ 2 56.94	+ 21	— 4	+ 5	6	23.41	
			14.0110	27.4010	+ 33	—2.4	— .5	40 42 2.44	— 5 38.54	— 43	— 45	—10	6	22.98	60.0
			16.0677	23.0190	— 28	—1.1	— .8	40 39 18.86	— 2 55.57	— 22	— 27	— 5	6	23.81	61.1
			21.8637	16.2227	— 48	— .6	—1.4	40 38 46.33	— 2 22.41	— 18	— 27	— 4	6	23.49	
			21.3430	19.3777	+ 6	—1.0	— .3	40 35 32.91	+ 49.67	+ 6	— 20	+ 2	6	23.52	60.3
			21.2407	18.6897	— 1	— .7	+ .4	40 37 26.77	— 1 4.46	— 8	— 6	— 2	7	22.22	
			19.0277	19.7443	— 3	— .3	— .1	40 36 40.64	— 18.10	— 3	— 7	— 1	9	23.52	
			31.0970 ^{IV}	7.7687 ^{II}	— 17	+ .1	+ .7	40 46 12.83	— 9 49.41	— 91	+ 10	—17	6	22.50	60.3
	III 2	D	12.8997	24.9987	—111	.0	+ .9	40 41 28.49	— 5 5.43	— 38	+ 12	— 9	6	22.77	
			8.5193 ^{II}	29.0700 ^{IV}	— 6	+ .1	— .2	40 27 43.10	+ 8 39.25	+ 81	— 1	+17	8	23.40	
			16.9943	20.1293	— 39	— .2	—1.9	40 35 4.38	+ 1 19.12	+ 9	— 27	+ 3	6	23.41	58.8a
			11.9263 ^{II}	27.6190 ^{IV}	+ 10	—4.3	—4.8	40 29 46.89	+ 6 36.54	+ 66	—1.29	+12	7	22.99	58.8
			31.8513 ^{IV}	7.6093 ^{II}	— 11	+1.8	+ .2	40 46 36.42	—10 12.51	— 93	+ 31	—23	11	23.17	55.8
			34.0837 ^{IV}	8.6847 ^{II}	+ 64	—1.3	— .2	40 25 39.98	+10 41.93	+ 96	— 23	+18	6	22.88	
			32.3840 ^{IV}	7.1673 ^{II}	— 9	— .9	—1.2	40 25 45.45	+10 37.14	+ 95	— 30	+19	6	23.49	
			12.4697	24.3417	—165	— .3	—2.6	40 31 23.15	+ 4 59.56	+ 37	— 38	+10	7	22.87	55.2
May 10	II 1	R	21.7573	18.4613	+ 3	—1.0	—2.9	40 37 46.83	— 1 23.29	— 11	— 52	— 3	6	22.94	54.4
			18.8593	20.1053	— 6	—1.5	— .2	40 36 54.64	— 31.47	— 4	— 27	— 1	6	22.91	54.4
			23.9620	16.9920	— 30	— .0	+ .2	40 33 26.40	+ 2 56.19	+ 21	+ 2	+ 5	6	22.93	
			25.8147	12.4163	—104	—1.0	—2.1	40 42 2.64	— 5 38.28	— 43	— 42	—10	6	23.47	52.8
			23.6210	16.6440	+ 8	—1.4	—1.2	40 39 19.05	— 2 56.31	— 22	+ 37	— 5	6	22.90	55.2
			17.3460	23.0210	+ 8	— .1	+ .1	40 38 46.53	— 2 23.41	— 18	0	— 4	6	22.96	
			18.9637	20.9280	— 1	+ .7	+ .2	40 35 33.12	+ 49.63	+ 6	+ 13	+ 2	6	23.02	
			20.3460	22.8757	+ 35	— .9	— .2	40 37 26.97	— 1 4.01	— 8	— 14	— 2	7	22.79	
	III 1	R	20.8237	20.0850	+ 3	+1.6	.0	40 36 40.82	— 18.67	— 3	+ 25	— 1	9	22.45	
			25.4527	13.3513	— 73	+2.9	+1.6	40 41 28.72	— 5 5.59	— 38	+ 66	— 9	6	23.33	55.3
			31.1447 ^{IV}	10.5677 ^{II}	+ 4	—1.7	— .6	40 27 43.30	+ 8 39.94	+ 81	— 34	+17	8	23.96	54.4
			22.1440	19.0487	+ 16	— .4	+ .6	40 35 4.61	+ 1 18.25	+ 9	+ 1	+ 3	6	23.05	a
			28.0230 ^{IV}	12.4063 ^{II}	— 9	+ .8	+ .3	40 29 47.12	+ 6 34.57	+ 66	— 8	+12	7	22.46	55.0
			27.7770	12.0727	— 8	—2.4	.0	40 43 0.79	— 6 36.79	— 49	— 38	—14	10	23.09	50.8
			8.8860 ^{II}	33.0887 ^{IV}	+ 37	—1.9	—1.5	40 46 36.61	—10 11.64	— 93	— 49	—23	11	23.43	52.1d
			8.3597 ^{II}	33.7587 ^{IV}	+ 51	+1.2	— .3	40 25 40.20	+10 41.90	+ 96	+ 15	+18	6	23.45	d
May 12	II 1	D	16.2333	23.2220	— 16	+ .5	+ .2	40 39 19.46	— 2 56.55	— 22	+ 10	— 5	6	22.80	60.9
			23.0143	17.3070	— 7	+ .9	+2.1	40 38 46.97	— 2 24.19	— 18	+ 41	— 4	6	23.03	
			20.3680	18.4444	— 9	+1.4	+1.7	40 35 33.57	+ 48.58	+ 6	+ 44	+ 2	6	22.73	
			21.5167	18.9430	+ 6	— 4	.0	40 37 27.38	— 1 5.05	— 8	— 7	— 2	7	22.23	60.9
	III 2	D	19.3997	20.1383	— 1	+ .1	— .1	40 36 41.23	— 18.66	— 3	— 0	— 1	9	22.62	
			31.5363 ^{IV}	8.2363 ^{II}	— 3	— .4	—1.0	40 46 13.50	— 9 48.73	— 91	— 19	—17	6	23.56	
			14.3627	26.4617	+ 39	— .2	+ .5	40 41 29.18	— 5 5.81	— 38	+ 4	— 9	6	23.00	
			8.2097 ^{II}	28.7350 ^{IV}	— 7	+ .2	—1.0	40 27 43.29	+ 8 38.61	+ 81	+ 16	+17	8	23.12	
	III 1	D	17.2607	20.3470	— 32	— .2	— .3	40 35 5.07	+ 1 17.90	+ 9	— 7	+ 3	6	23.08	
			11.6847 ^{II}	27.2763 ^{IV}	+ 20	+1.0	+ .3	40 29 47.60	+ 6 34.01	+ 66	+ 20	+12	7	22.66	58.6
			11.5583	27.2940	— 80	— .8	— .6	40 43 1.18	— 6 37.40	— 49	— 20	—14	10	23.05	55.0
			29.5320 ^{IV}	5.2850 ^{II}	—100	— .6	— .2	40 46 36.98	—10 12.42	— 93	— 11	—23	11	23.40	56.9
	III 2	D	32.4390 ^{IV}	7.0373 ^{II}	— 11	—3.1	—2.3	40 25 40.58	+10 41.81	+ 96	— 78	+18	6	22.81	
			31.6543 ^{IV}	6.4683 ^{II}	— 42	—1.9	— .8	40 25 46.08	+10 36.28	+ 95	— 40	+19	6	23.16	
			12.6827	24.5213	—143	— .8	— .0	40 31 23.73	+ 4 58.77	+ 37	— 12	+10	7	22.92	56.4
			22.1813	18.8423	+ 15	+1.6	+ .2	40 37 47.43	— 1 24.41	— 11	+ 28	— 3	6	23.22	
	III 3	R	19.6490	20.9423	+ 3	— .5	+ .1	40 36 55.22	— 32.69	— 4	— 7	— 1	6	22.47	
			23.9517	17.0007	+ 30	— .9	— .8	40 33 26.97	+ 2 55.71	+ 21	— 24	+ 5	6	22.76	

OBSERVATIONS WITH THE ZENITH TELESCOPE.

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1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
May															
12	III 9	D	25.6963	12.2587	-120	+1.1	+ .2	40 42 3.18	- 5 39.23	- 43	+ 20	-10	6	40 36 23.68	56.8
13	II 1	R	22.0733	15.0517	- 88	+1.4	+2.5	40 39 19.71	- 2 57.20	- 22	+ 54	- 5	6	22.84	62.6
	2		16.2707	21.9787	- 45	+ .8	+2.6	40 38 47.21	- 2 24.11	- 18	+ 46	- 4	6	23.40	
	3		19.9447	21.8603	+ 15	+2.7	+1.6	40 35 33.81	+ 48.44	+ 6	+ 63	+ 2	6	23.02	62.6
	4		19.9503	22.5793	+ 30	+ .8	+2.0	40 37 27.61	- 1 6.50	- 8	+ 37	- 2	7	[21.45]	62.5d
May															
26	II 1	R	21.7293	20.9953	+ 9	- .6	- .5	40 36 41.45	- 18.57	- 3	- 16	- 1	9	22.77	62.4a
	2		23.0963	16.0077	- 28	- .7	- .6	40 39 22.64	- 2 59.04	- 22	- 18	- 5	6	23.18	60.2
	3		17.0517	22.8563	+ 2	- .8	-1.1	40 38 50.23	- 2 26.67	- 18	- 26	- 4	6	23.14	
	4		19.3373	21.1433	+ 3	+ .4	- .2	40 35 36.97	+ 45.64	+ 6	+ 4	+ 2	6	22.79	59.0
	5		19.7093	22.3930	+ 25	- .2	- .2	40 37 30.59	- 1 7.87	- 8	- 5	- 2	7	22.64	
	6		19.4557	18.6127	- 7	- .1	- .8	40 36 44.39	- 21.28	- 3	- 6	- 1	9	23.10	
	7		8.7630 ⁱⁱ	32.2570 ^{iv}	+ 16	+2.9	+3.1	40 46 17.10	- 9 53.68	- 91	+ 85	-17	6	23.25	
	8		26.8707	14.6253	+ 79	- .1	- .8	40 41 32.87	- 5 9.61	- 38	- 6	- 9	6	22.79	57.6
	9		29.9290 ^{iv}	9.5380 ⁱⁱ	+ 2	- .7	- .3	40 27 47.12	+ 8 35.24	+ 81	- 15	+17	8	23.27	
	10		22.4120	19.4543	+ 24	-2.2	- .5	40 35 8.79	+ 1 14.79	+ 9	- 41	+ 3	6	23.35	57.6
	III 1	R	28.5067 ^{iv}	13.0313 ⁱⁱ	- 30	-1.1	-2.5	40 29 51.45	+ 6 30.95	+ 66	- 49	+12	7	22.76	56.8
	2		30.0383	14.1933	+292	- .3	- .3	40 43 4.68	- 6 41.10	- 49	- 9	-14	10	22.96	55.1
	3		9.2137 ⁱⁱ	33.5783 ^{iv}	+ 54	- .3	- .8	40 46 40.36	-10 15.77	- 93	- 15	-23	11	23.39	
	4		8.9077 ⁱⁱ	34.0973 ^{iv}	+ 69	+2.7	+1.8	40 25 44.48	+10 36.66	+ 96	+ 65	+18	6	22.99	
	5		8.3470 ⁱⁱ	33.3603 ^{iv}	+ 37	- .4	+1.2	40 25 49.85	+10 32.12	+ 95	+ 9	+19	6	23.26	55.7
	6		23.9537	12.2640	-193	- .4	- .1	40 31 27.26	+ 4 54.88	+ 37	- 8	+10	7	22.60	
	7		16.6870	20.1787	- 48	-1.0	- .6	40 37 51.06	- 1 28.11	- 11	- 23	- 3	6	22.64	55.1
	8		21.0780	19.6387	+ 4	+1.2	+ .3	40 36 58.77	- 36.38	- 4	+ 23	- 1	6	22.63	
	9		17.1490	23.9230	+ 32	+ .2	+ .3	40 33 30.49	+ 2 51.24	+ 21	+ 7	+ 5	6	22.12	
	10		13.5987	27.1550	+ 44	-1.4	- .4	40 42 6.57	- 5 42.65	- 43	- 27	-10	6	23.18	54.8
May															
27	II 1	D	16.9637	23.9600	+ 29	- .6	- .4	40 39 22.84	- 2 59.38	- 22	- 15	- 5	6	23.10	63.6
	2		21.9660	16.1270	- 49	+ .3	+ .2	40 38 50.47	- 2 27.41	- 18	+ 7	- 4	6	22.97	
	3		21.6173	19.8260	- 11	+ .8	+ .4	40 35 37.22	+ 45.29	+ 6	+ 17	+ 2	6	22.82	
	4		20.7663	18.0570	- 13	- .2	- .4	40 37 30.82	- 1 8.42	- 8	- 8	- 2	7	22.29	62.4
	5		18.7890	19.6513	- .6	-1.0	-1.5	40 36 44.61	- 21.77	- 3	- 35	- 1	9	22.54	
	6		31.7940 ^{iv}	8.3233 ⁱⁱ	+ 1	+ .1	- .2	40 46 17.35	- 9 53.05	- 91	- 1	-17	6	23.27	61.9
	9		17.5290	20.4600	- 24	+ .8	+ .4	40 35 9.05	+ 1 14.00	+ 9	+ 17	+ 3	6	23.40	62.0
	10		12.4897 ⁱⁱ	27.9343 ^{iv}	- 9	+ .5	- .0	40 29 51.72	+ 6 30.23	+ 66	+ 8	+12	7	22.88	62.0
	III 1	D	9.5366	25.4360	-347	- .7	-1.8	40 43 4.92	- 6 40.86	- 49	- 34	-14	10	23.19	57.3
	2		31.8560 ^{iv}	7.4890 ⁱⁱ	- 11	-1.4	-1.8	40 46 40.59	-10 15.67	- 93	- 46	-23	11	23.41	
	3		33.4213 ^{iv}	8.2193 ⁱⁱ	+ 38	-1.8	- .7	40 25 44.75	+10 36.89	+ 96	- 37	+18	6	22.47	
	4		31.2313 ^{iv}	6.1647 ⁱⁱ	- 58	-2.0	-2.4	40 25 50.11	+10 33.23	+ 95	- 62	+19	6	23.92	
	5		13.6460	25.3343	- 52	- .3	- .7	40 31 27.41	+ 4 55.20	+ 37	- 14	+10	7	23.01	58.4
	6		21.6763	18.2003	- 1	- .6	-1.0	40 37 51.31	- 1 27.83	- 11	- 22	- 3	6	23.18	
	7		19.8600	21.3267	+ 7	+1.5	+1.8	40 36 59.03	- 37.08	- 4	+ 46	- 1	6	22.42	58.4d
	8		22.9880	16.1913	- 25	- .3	-1.0	40 33 30.75	+ 2 51.67	+ 21	- 17	+ 5	6	22.57	
June															
3	II 1	R	26.3630	12.7950	- 49	+ .1	- .7	40 42 6.80	- 5 42.71	- 43	- 7	-10	6	23.55	58.4
	2		23.0497	15.8577	- 25	+ .8	+2.3	40 39 24.36	- 3 1.66	- 22	+ 41	- 5	6	22.90	65.1
	3		16.6540	22.5647	- 21	+1.5	+ .2	40 38 52.07	- 2 29.30	- 18	+ 27	- 4	6	22.88	
	4		18.7577	20.4890	- 5	- .1	- .0	40 35 38.92	+ 43.73	+ 6	- 1	+ 2	6	22.78	65.8
	5		18.8330	21.6150	+ 6	+ .4	+1.0	40 37 32.44	- 1 10.31	- 8	+ 19	- 2	7	22.29	65.4
	6		21.0650	20.1250	+ 4	- .7	+ .2	40 36 46.23	- 23.76	- 3	- 9	- 1	9	22.43	
	7		8.6027 ⁱⁱ	32.1667 ^{iv}	+ 12	+1.2	+1.3	40 46 19.20	- 9 55.44	-1.05	+ 36	-17	6	22.96	
June															
4	II 1	D	26.2473	13.9017	+ 8	+ .5	-1.1	40 41 35.06	- 5 11.96	- 38	- 6	- 9	6	22.63	64.6
	2		17.2473	24.4070	+ 52	-1.5	-2.0	40 39 24.52	- 3 1.04	- 22	- 49	- 5	6	22.78	63.2
	3		22.9463	17.0513	- 0	-1.3	-2.0	40 38 52.24	- 2 28.95	- 18	- 45	- 4	6	22.68	
	4		20.9063	19.1917	+ 1	- .9	- .8	40 35 39.11	+ 43.33	+ 6	- 24	+ 2	6	22.34	62.8
	5		21.5270	18.7570	+ 4	- .3	+ .4	40 37 32.62	- 1 10.00	- 8	- 0	- 2	7	22.59	
	6		17.9797	18.9100	+ 12	-1.0	-1.5	40 36 46.41	- 23.54	- 3	- 35	- 1	9	22.57	
	7		31.4743 ^{iv}	7.9037 ⁱⁱ	- 9	- .1	-1.2	40 46 19.41	- 9 55.55	-1.05	- 17	-17	6	22.53	

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther- mom.		
						A	B		Micrometer.	δ	l	r	Mer				
June 8	II	1	R	22.9380	15.7307	- 43	+ .1	.0	40 39 25.24	- 3	2.00	- 23	+ 1	- 5	6	23.04	62.2
		3		19.2993	21.0010	+ 1	- .1	-1.2	40 35 39.82	+ 43.00	+ 6	- 16	+ 2	6		22.80	62.6
		4		19.3780	22.1570	+ 18	- .9	-1.8	40 37 33.26	- 1 10.26	- 8	- 37	- 2	7		22.60	
		5		22.5467	21.5957	+ 17	+ .6	- .1	40 36 47.05	- 24.07	- 3	+ 8	- 1	9		23.11	
		6		8.0543 ⁱⁱ	31.6293 ^{iv}	- 4	-1.4	-1.9	40 46 20.17	- 9 55.67	-1.05	- 46	-17	6		22.88	
		7		26.0217	13.6483	- 19	- .8	- .6	40 41 36.10	- 5 12.60	- 38	- 20	- 9	6		22.89	
		8		30.1650 ^{iv}	9.8687 ⁱⁱ	0	-1.7	-2.3	40 27 50.11	+ 8 32.84	+ 95	- 56	+17	8		23.59	
June 9	II	1	D	22.1140	19.2817	+ 14	+ .2	+ .8	40 35 10.10	+ 1 11.60	+ 9	+ 13	+ 3	6		24.01	59.4a
		2		15.3553	22.5833	- 66	+ .8	+ 2.4	40 39 25.43	- 3 2.47	- 22	+ 42	- 5	6		23.17	67.2
		2		21.0600	15.1210	- 99	+ .2	+ 1.6	40 38 53.04	- 2 29.81	- 18	+ 23	- 4	6		23.30	
		3		20.5827	18.8997	- 3	- .2	+ .9	40 35 40.01	+ 42.53	+ 6	+ 9	+ 2	6		22.77	66.1
		4		19.8627	17.0223	- 39	+ .6	+ .2	40 37 33.44	- 1 11.67	- 8	+ 12	- 2	7		21.86	
		5		20.5180	21.4937	- 8	- .5	- .2	40 36 47.23	- 24.65	- 3	- 10	- 1	9		22.53	
		6		35.1837 ^{iv}	11.5910 ⁱⁱ	+106	+1.2	+1.1	40 46 20.38	- 9 56.40	-1.05	+ 33	-17	6		23.15	65.4
		7		14.5390	26.9147	+ 76	+ .5	+ .7	40 41 36.32	- 5 12.90	- 38	+ 17	- 9	6		23.18	
June 10	II	8		10.1417 ⁱⁱ	30.3717 ^{iv}	+ 1	.0	+1.3	40 27 50.32	+ 8 31.17	+ 95	+ 16	+17	8		22.85	
		10		13.3260 ⁱⁱ	28.6243 ^{iv}	- 40	+ .2	+ .7	40 29 55.14	+ 6 26.45	+ 80	+ 12	+12	6		22.69	65.0
		1	R	23.0110	15.7897	- 39	+1.2	+2.0	40 39 25.46	- 3 2.37	- 22	+ 44	- 5	6		23.32	74.3
		2		16.2397	22.1900	- 41	+ .7	+1.1	40 38 53.24	- 2 30.25	- 18	+ 25	- 4	6		23.08	
		3		18.7803	20.4690	- 5	+ .1	- .3	40 35 40.19	+ 42.66	+ 6	- 2	+ 2	6		22.97	
		4		19.9813	22.7927	+ 35	+ .4	+ .1	40 37 33.66	- 1 11.13	- 8	+ 8	- 2	7		22.58	
		5		21.5140	20.5343	+ 8	- .4	- .8	40 36 47.43	- 24.77	- 3	- 17	- 1	9		22.54	
		6		9.0723 ⁱⁱ	32.6830 ^{iv}	+ 28	+1.1	+ .7	40 46 20.61	- 9 56.66	-1.05	+ 26	-17	6		23.05	
		7		25.6447	13.2350	- 59	+1.3	+1.2	40 41 36.55	- 5 13.41	- 38	+ 35	- 9	6		23.08	72.7
		8		30.6877 ^{iv}	10.4143 ⁱⁱ	+ 1	-1.1	-2.0	40 27 50.54	+ 8 32.26	+ 95	- 42	+17	8		23.58	
		9		22.7780	19.9450	+ 34	-2.1	-1.0	40 35 12.57	+ 1 11.67	+ 9	- 46	+ 3	6		23.96	
		10		27.1307 ^{iv}	17.8223 ⁱⁱ	+ 21	-1.3	-1.4	40 29 55.40	+ 6 26.86	+ 80	- 38	+12	7		22.87	71.8
	III	1	R	29.8003	13.8053	+253	-1.4	-1.1	40 43 8.60	- 6 44.79	- 49	- 36	-14	10		22.92	70.8
		2		8.1283 ⁱⁱ	32.6333 ^{iv}	+ 15	- .8	-1.4	40 46 44.23	-10 19.22	-1.07	- 30	-23	11		23.52	71.1
		3		7.6590 ⁱⁱ	32.7067 ^{iv}	+ 8	- .6	- .1	40 25 48.97	+10 32.92	+1.10	- 11	+18	6		23.12	
		4		7.0947 ⁱⁱ	31.9693 ^{iv}	- 20	-1.8	-2.0	40 25 54.26	+10 28.47	+1.09	- 53	+19	6		23.54	
		5		27.2803	15.7877	+153	- .8	+2.7	40 31 31.48	+ 4 50.78	+ 37	+ 22	+10	7		23.02	
		6		19.2093	22.8607	+ 33	- .8	.0	40 37 55.47	- 1 32.35	- 11	- 12	- 3	6		22.92	
		7		22.6157	21.0180	+ 26	+1.2	- .3	40 37 3.15	- 40.49	- 4	+ 15	- 1	6		22.82	
		8		17.4600	24.0893	+ 44	- .9	- .3	40 33 34.36	+ 2 47.62	+ 21	- 18	+ 5	6		22.62	70.1
June 11	III	9		14.0007	27.7310	+104	- .8	-1.5	40 42 10.83	- 5 47.19	- 43	- 31	-10	6		22.86	
June 12	II	1	D	11.4683	27.5190	- 74	- .1	.0	40 43 8.89	- 6 45.38	- 49	- 1	-14	10		22.97	73.8
		1	D	16.9260	24.1090	+ 32	-2.6	-3.4	40 39 25.86	- 3 1.58	- 21	- 84	- 5	6		23.24	74.8
		2		21.7957	15.8257	- 63	+1.0	+ .8	40 38 53.66	- 2 30.69	- 17	+ 26	- 4	6		23.08	
June 14	II	3		21.5413	19.8757	+ 10	- .8	- .4	40 35 40.64	+ 42.11	+ 5	- 19	+ 2	6		22.69	74.3
		1	D	16.3903	23.6163	0	- .6	-2.2	40 39 26.24	- 3 2.58	- 21	- 37	- 5	6		23.09	67.4
		2		22.6047	16.6387	- 20	-1.4	-1.2	40 38 54.08	- 2 30.70	- 17	- 38	- 4	6		22.85	
		3		21.4143	19.7663	+ 8	+ .2	- .4	40 35 41.09	+ 41.66	+ 5	- 2	+ 2	6		22.86	
		4		21.7603	18.9093	+ 9	+1.1	+ .3	40 37 34.50	- 1 12.06	- 8	+ 21	- 2	7		22.62	67.0
		5		19.4953	20.5010	0	-1.6	-1.9	40 36 48.29	- 25.41	- 3	- 49	- 1	9		22.44	
		6		35.8087 ^{iv}	12.1947 ⁱⁱ	+126	+ .6	+ .1	40 41 21.60	- 9 53.99	- 99	+ 11	-17	6		23.62	
		7		14.9777	27.4117	+130	- .6	- .7	40 41 37.60	- 5 14.51	- 36	- 18	- 9	6		22.52	66.6
		8		9.7293 ⁱⁱ	29.9410 ^{iv}	- 1	- .4	-1.2	40 27 51.51	+ 8 30.70	+ 89	- 21	+17	8		23.14	
		9		18.6773	21.3737	+ 1	+ .3	- .2	40 35 13.65	+ 1 8.13	+ 8	+ 2	+ 3	6		21.97	a
		10		12.9900 ⁱⁱ	28.2667 ^{iv}	- 26	- .2	-1.1	40 29 56.53	+ 6 25.94	+ 75	- 17	+12	7		23.24	65.9
	III	1	D	10.8007	26.8940	-162	- .4	-1.4	40 43 9.76	- 6 46.23	- 46	- 24	-14	10		22.79	61.2
		2		30.1060 ^{iv}	5.5217 ⁱⁱ	- 89	- .4	-1.1	40 46 45.37	-10 20.96	-1.02	- 20	-23	11		23.07	61.0
		3		34.0560 ^{iv}	9.0423 ⁱⁱ	+ 68	-3.7	-3.7	40 25 50.28	+10 32.21	+1.02	-1.05	+18	6		22.70	
		4		31.3469 ^{iv}	6.5390 ⁱⁱ	- 46	- .9	-1.9	40 25 55.55	+10 26.72	+1.02	- 38	+19	6		23.16	60.8
		5		13.4723	24.9493	- 81	+ .7	- .1	40 31 32.73	+ 4 42.79	+ 32	+ 9	+10	7		23.10	

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther- mom.
						A	B		Micrometer.	δ	l	r	Mer		
June 15	II	1 R	23.1823	15.9227	-28	+1.3	+1.5	40 39 26.42	-3 3.36	-21	+39	-5	6	40 36 23.25	70.3
		2	15.6340	21.6307	-71	+ .3	+ .2	40 38 54.26	-2 31.34	-17	+ 8	-4	6	22.85	
		3	19.3667	21.0097	+ 1	- .6	.0	40 35 41.30	+ 41.52	+ 5	- 9	+ 2	6	22.86	69.5
		4	19.5533	22.4333	+ 24	+ .4	+1.1	40 37 34.70	-1 12.83	- 8	+ 20	- 2	7	22.04	
		5	22.3440	21.3347	+ 17	- .4	- .7	40 36 48.50	-25.55	- 3	- 15	- 1	9	22.85	
		6	8.7223 ⁱⁱ	32.3683 ^{iv}	+ 13	- .3	- .1	40 46 21.83	-9 57.51	-99	- 6	-17	6	23.16	68.6
		7	25.4000	12.9547	-88	- .7	- .6	40 41 37.85	-5 14.24	-36	- 18	- 9	6	23.04	
		8	31.5880 ^{iv}	11.3690 ⁱⁱ	+ 3	+ .6	- .1	40 27 51.75	+8 30.89	+89	+ 8	+17	8	23.86	
		9	22.9817	20.1473	+ 35	+ .4	- .1	40 35 13.91	+ 1 9.18	+ 8	+ 5	+ 3	6	23.31	
		10	27.1400 ^{iv}	11.8713 ⁱⁱ	+ 21	-1.5	-1.4	40 29 56.80	+ 6 25.86	+ 75	- 42	+12	7	23.18	67.1
June 17	III	1 R	30.1150	14.0707	+292	-1.3	- .9	40 43 10.06	- 6 46.14	-46	- 32	-14	10	23.10	65.6
		2	7.5430 ⁱⁱ	32.1317 ^{iv}	- 7	+ .5	- .2	40 46 45.67	-10 21.28	-1.02	+ 5	-23	11	23.30	66.1
		3	8.7020 ⁱⁱ	33.6783 ^{iv}	+ 52	.0	- .9	40 25 50.63	+10 31.22	+1.02	- 11	+18	6	23.00	
		4	7.9033 ⁱⁱ	32.7320 ^{iv}	+ 14	-2.8	-2.4	40 25 55.89	+10 27.40	+1.02	- 74	+19	6	23.82	
		5	26.2777	14.8374	+ 56	-1.2	+2.0	40 31 33.06	+ 4 49.21	+ 32	- 44	+10	7	22.32	65.2
		6	19.1923	22.9113	+ 34	- .6	+1.2	40 37 57.12	- 1 34.06	- 11	+ 6	- 3	6	23.04	
		7	21.3033	19.6357	+ 7	+1.6	+ .5	40 37 4.79	- 42.15	- 5	+ 32	- 1	6	22.96	
		8	16.9993	23.5610	+ 17	- .5	+ .1	40 33 36.50	+ 2 45.84	+ 19	- 6	+ 5	6	22.58	
		9	13.8800	27.6900	+ 95	-1.4	-1.0	40 42 12.44	-5 49.19	-40	- 35	-10	6	22.46	65.9
		10	16.5460	23.8037	+ 1	-1.3	-1.4	40 39 26.71	-3 3.39	-21	- 38	- 5	6	22.74	78.1
June 18	II	2	23.2100	17.2190	+ 10	- .4	- .6	40 38 54.58	-2 31.40	- 17	- 14	- 4	6	22.89	
		3	20.8590	19.2243	+ 1	-1.2	- .3	40 35 41.65	+ 41.31	+ 5	- 22	+ 2	6	22.87	
		4	21.7213	18.8603	+ 8	-1.0	-1.2	40 37 35.05	-1 12.31	- 8	- 30	- 2	7	22.41	78.2
		5	18.7587	19.7873	- 6	-1.5	-1.4	40 36 48.85	-25.98	- 3	- 41	- 1	9	22.51	
		6	32.7213 ^{iv}	9.0660 ⁱⁱ	+ 29	- .8	-1.2	40 46 22.25	-9 57.79	-99	- 28	-17	6	23.08	77.8
		7	11.8930	24.4187	-201	+1.7	+2.1	40 41 38.30	-5 15.99	-36	+ 54	- 9	6	22.46	
		8	9.3653 ⁱⁱ	29.5370 ^{iv}	- 1	- .4	- .7	40 27 52.17	+8 29.69	+89	- 15	+17	8	22.85	
		9	13.2697 ⁱⁱ	28.5057 ^{iv}	-37	+ .8	+ .7	40 29 57.31	+ 6 24.88	+ 75	+ 22	+12	7	23.35	76.1
		10	13.2697 ⁱⁱ	28.5057 ^{iv}	-37	+ .8	+ .7	40 29 57.31	+ 6 24.88	+ 75	+ 22	+12	7	23.35	76.1
	III	1 D	10.9837	27.0980	-135	- .7	- .2	40 43 10.63	-6 46.83	-46	- 13	-14	10	23.17	74.0
		3	31.9013 ^{iv}	6.9553 ⁱⁱ	- 24	- .6	-1.3	40 25 51.30	+10 30.26	+1.02	- 26	+18	6	22.56	
		4	30.5727 ^{iv}	5.7870 ⁱⁱ	- 76	+ .6	- .1	40 25 56.55	+10 26.08	+1.02	+ 8	+19	6	23.98	
		5	13.6513	25.0707	-64	+1.2	+ .1	40 31 33.70	+ 4 48.38	+ 32	+ 20	+10	7	22.77	
		6	22.0593	18.3087	+ 5	+ .9	- .2	40 37 57.79	-1 34.78	- 11	+ 12	- 3	6	23.05	
June 20	II	7	18.4053	20.0577	-12	- .3	-1.3	40 37 5.47	-41.72	- 5	- 21	- 1	6	[23.54]	73.1d
		8	23.3087	16.7643	+ 1	+ .3	- .8	40 33 37.19	+ 2 45.36	+ 19	- 5	+ 5	6	22.80	
		9	24.0470	10.1900	-347	- .4	- .7	40 42 13.12	-5 49.26	-40	- 15	-10	6	23.27	72.9
		1	23.1620	15.8973	-30	- .6	.0	40 39 26.82	-3 3.49	-21	- 9	- 5	6	23.04	79.1
		2	16.4190	22.4373	-31	+ .2	- .1	40 38 54.71	-2 31.99	-17	+ 2	- 4	6	22.59	79.1
	III	1 R	18.4570	20.0760	-11	+1.4	+ .8	40 35 41.80	+ 40.88	+ 5	+ 32	+ 1	6	23.12	
		2	24.4103	17.1450	+ 50	+ .8	- .6	40 39 27.04	-3 3.70	-21	- 2	- 5	6	23.12	
		3	19.2960	25.2747	+119	+ .7	+ .1	40 38 54.95	-2 31.37	-17	+ 12	- 4	6	23.55	74.3
		4	19.5790	21.2213	+ 5	-2.3	-3.1	40 35 42.08	+ 41.51	+ 5	- 76	+ 1	6	22.95	
		5	20.4147	23.3003	+ 46	- .8	+ .1	40 37 35.45	-1 13.03	- 8	- 11	- 2	7	22.28	
June 21	II	6	21.2477	20.2097	+ 6	- .4	-1.9	40 36 49.24	-26.24	- 3	- 30	- 1	9	22.75	73.4
		7	8.1757	31.8583	- 0	-1.2	-2.0	40 46 22.75	-9 58.40	-99	- 44	-17	6	22.81	
		7	26.3447	13.8623	+ 11	.0	- .4	40 41 38.85	-5 15.43	-36	- 5	- 9	6	22.98	
		10	27.2823 ^{iv}	12.0553 ⁱⁱ	+ 15	-2.1	-2.2	40 29 57.93	+ 6 24.79	+ 75	- 61	+12	7	23.05	71.2
		11	30.3157	14.2320	+318	-2.4	-1.3	40 43 11.35	-6 47.20	-46	- 55	-14	10	23.10	67.6
	III	2 R	9.6170 ⁱⁱ	34.2397 ^{iv}	+ 78	+ .5	- .2	40 46 46.98	-10 22.35	-1.02	+ 5	-23	11	23.54	
		3	9.0700 ⁱⁱ	33.9690 ^{iv}	+ 65	+1.3	- .2	40 25 52.17	+10 29.31	+1.02	+ 18	+18	6	22.92	
		4	7.6717 ⁱⁱ	32.4107 ^{iv}	+ 1	-2.4	-2.5	40 25 57.42	+10 25.10	+1.02	- 70	+19	6	23.09	67.8
		6	18.0483	21.8493	- 1	- .3	+ .5	40 37 58.70	-1 36.04	-11	+ 1	- 3	7	22.60	
		7	21.4290	19.7017	+ 8	+ .4	- .1	40 37 6.40	-43.66	- 5	+ 5	- 1	6	22.79	
June 22	II	8	18.1717	24.6617	+ 81	+ .3	- .3	40 33 38.11	+ 2 44.19	+ 19	+ 1	+ 5	6	22.61	67.8
		9	14.7577	28.6123	+203	-1.6	.0	40 42 14.04	-5 50.59	-40	- 25	-10	6	22.76	

1891.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.		
						A	B		Micrometer.	δ	l	r	Mer				
June 22	II	1	D	14.9940	22.3150	- 85	+ .2	+1.4	40 39 27.28	- 3	4.77	- 21	+ 20	- 5	6	40 36 22.51	78.0
		2		22.5197	16.5040	- 26	- .1	+ .1	40 38 55.25	- 2	31.94	- 17	0	- 4	6	23.16	
		3		19.7767	18.1690	- 14	- .5	- .1	40 35 42.86	+ 40.59	+ 5	-	9	+ 1	6	22.98	
		4		21.9363	18.1510	- 11	- .6	-1.0	40 37 35.72	- 1	12.88	- 8	- 22	- 2	7	22.59	77.8
		5		17.8397	18.9060	- 16	-2.9	- .5	40 36 49.51	- 26.90	- 3	-	53	- 1	9	22.13	
		6		31.8130 ^{iv}	8.1360 ⁱⁱ	- 1	-2.1	-2.4	40 46 23.08	- 9	58.26	- 99	- 63	-18	6	23.08	
		7		12.6720	25.1799	-118	-2.1	-1.6	40 41 39.29	- 5	15.60	- 36	- 53	- 9	6	22.68	75.
		8		9.0497 ⁱⁱ	29.2160 ^{iv}	- 1	-1.3	-1.8	40 27 53.14	+ 8	29.55	+ 89	- 43	+17	8	23.40	
		10		11.5823 ⁱⁱ	26.7550 ^{iv}	+ 35	0	- .8	40 29 58.33	+ 6	23.47	+ 75	- 10	+12	7	22.64	74.9
	III	1	D	12.4693	28.6063	+ 82	-1.7	-1.8	40 43 11.79	- 6	47.95	- 46	- 50	-14	10	22.84	73.9
		2		30.4007 ^{iv}	5.7160 ⁱⁱ	- 79	+ .8	- .2	40 46 47.42	-10	23.52	-1.02	+ 9	-23	11	22.85	
		3		34.3783 ^{iv}	9.5040 ⁱⁱ	+ 82	- .0	+ .2	40 25 52.71	+10	28.72	+1.02	+ 2	+18	6	22.71	74.7
		4		31.9827 ^{iv}	7.2657 ⁱⁱ	- 16	-1.0	-1.0	40 25 57.95	+10	24.50	+1.02	- 28	+19	6	23.44	73.9
		6		21.8460	18.0397	- 1	+1.1	+ .2	40 37 59.25	- 1	36.17	- 11	+ 19	- 3	6	23.19	
		8		23.1097	16.6077	- 9	-1.7	- .8	40 33 33.67	+ 2	44.27	+ 19	- 37	+ 5	6	22.87	
June 27	II	9		25.3720	11.4643	-194	- .4	- .9	40 42 14.59	- 5	50.92	- 40	- 18	-10	6	23.05	73.7
		2	R	16.3307	22.3807	- 35	- .9	-1.7	40 38 56.01	- 2	32.78	- 17	- 36	- 4	6	22.72	76.8
		3		19.7153	21.2843	+ 6	- .9	- .7	40 35 43.26	+ 39.66	+ 5	-	23	+ 1	6	22.81	
		4		19.4240	22.3367	+ 22	-1.0	- .7	40 37 36.57	- 1	13.65	- 8	- 25	- 2	7	22.64	
		5		21.8700	20.7650	+ 12	- .6	- .0	40 36 50.40	- 27.95	- 3	-	9	- 1	9	22.41	
		6		8.2440 ⁱⁱ	31.9690 ^{iv}	+ 2	-1.2	-1.2	40 46 24.09	- 9	59.48	- 99	- 34	-18	6	23.16	76.4
		7		26.9333	14.3777	+ 68	+2.0	+ .9	40 41 40.29	- 5	17.42	- 36	+ 43	- 9	6	22.91	76.0
		8		31.3457 ^{iv}	11.2497 ⁱⁱ	+ 1	+1.5	+ .4	40 27 54.04	+ 8	27.78	+ 89	+ 29	+17	8	23.25	
June 28	II	10		27.6953 ^{iv}	12.5893 ⁱⁱ	+ 4	+1.9	+1.8	40 29 59.54	+ 6	21.73	+ 75	+ 53	+12	7	22.74	75.9
		2	D	23.3057	17.2330	+ 13	+1.2	+2.6	40 38 56.16	- 2	33.48	- 17	+ 54	- 4	6	23.07	74.9
		3		18.4433	16.8877	- 31	+1.0	+1.2	40 35 43.42	+ 39.23	+ 5	+ 31	+ 1	6	23.08		
		4		22.3613	19.4280	+ 23	+ .6	+ .1	40 37 36.74	- 1	14.18	- 8	+ 11	- 2	7	22.64	73.9
		5		20.4690	21.5780	+ 10	+1.3	+ .7	40 36 50.56	- 28.05	- 3	+ 29	- 1	9	22.85		
		6		31.9140 ^{iv}	8.1670 ⁱⁱ	+ 1	- .2	- .2	40 46 24.29	-10	0.03	- 99	- 6	-18	6	23.09	
		7		14.2953	26.8427	+ 62	-1.7	0	40 41 40.51	- 5	17.20	- 36	- 27	- 9	6	22.65	73.9
		8		9.7523 ⁱⁱ	29.8680 ^{iv}	- 1	- .4	- .9	40 27 54.24	+ 8	28.27	+ 89	- 18	+17	8	23.47	
		10		11.8537 ⁱⁱ	26.9753 ^{iv}	+ 25	- .0	- .1	40 29 59.78	+ 6	22.15	+ 44	+ 2	+12	7	22.58	73.1
	III	1	R	30.3643	14.1830	+ 320	-1.2	- .5	40 43 13.38	- 6	49.67	- 46	- 25	-14	10	22.96	70.9
		2		6.8860 ⁱⁱ	31.6173 ^{iv}	- 30	- .4	-1.2	40 46 49.21	-10	24.82	-1.02	- 21	-23	11	23.04	
		3		8.3807 ⁱⁱ	33.1867 ^{iv}	+ 33	+2.2	+ .3	40 25 54.58	+10	26.87	+1.02	+ 38	+18	6	23.09	
		4		8.7643 ⁱⁱ	33.3983 ^{iv}	+ 44	-1.1	-2.2	40 25 59.78	+10	22.55	+1.02	- 45	+19	6	23.15	
		5		26.9250	15.6307	+127	-1.2	-1.4	40 31 36.85	+ 4	45.70	+ 32	- 36	+10	7	22.68	70.6
		6		18.5373	22.4010	+ 16	-1.6	-1.7	40 38 1.15	- 1	37.67	- 11	- 47	- 3	6	22.93	
		7		22.6827	20.8793	+ 28	- .5	-2.3	40 37 8.83	- 45.64	- 5	- 37	- 1	6	22.82		
		8		17.7727	24.1827	+ 53	-1.4	- .4	40 33 40.59	+ 2	42.10	+ 19	- 27	+ 5	6	22.72	
July 3	II	9		13.3890	27.3453	+ 43	-1.7	- .5	40 42 16.48	- 5	52.75	- 40	- 33	-10	6	22.96	
		3	R	18.3350	19.8400	- 10	+ .7	+1.0	40 35 43.99	+ 38.00	+ 5	+ 23	+ 2	6	22.35	79.7	
		4		19.3737	22.3373	+ 22	- .1	- .1	40 37 37.28	- 1	14.94	- 8	- 3	- 2	7	22.28	
		5		22.3053	21.1810	+ 18	- .6	- .1	40 36 51.14	- 28.45	- 3	- 11	- 0	9	22.64		
		6		8.1597 ⁱⁱ	31.9397 ^{iv}	+ 1	- .6	- .1	40 46 25.01	-10	0.87	- 99	- 8	-18	6	22.95	79.3
		7		27.6223	15.0533	+147	- .1	- .1	40 41 41.33	- 5	17.96	- 36	- 3	- 9	6	22.95	
		8		31.0273 ^{iv}	10.9607 ⁱⁱ	+ 1	- .4	- .2	40 27 54.88	+ 8	27.04	+ 89	- 9	+17	8	22.97	78.4
		10		29.5677 ^{iv}	14.4700 ⁱⁱ	- 87	+ .2	0	40 30 0.76	+ 6	21.26	+ 75	+ 3	+12	7	22.99	
	III	1	D	9.6403	25.9490	-313	+ .1	0	40 43 14.64	- 6	51.29	- 46	+ 1	-14	10	22.86	75.8
		2		23.0960 ^{iv}	3.2840 ⁱⁱ	-180	+ .7	+1.0	40 46 50.31	-10	26.48	-1.02	+ 24	-23	11	22.93	
		3		32.5057 ^{iv}	7.7547 ⁱⁱ	- 6	-1.4	- .8	40 25 56.12	+10	25.41	- 1.02	- 32	- 18	6	22.47	
		4		30.7387 ^{iv}	6.1347 ⁱⁱ	- 62	- .5	- .5	40 26 1.34	+10	21.53	+1.02	- 14	+19	6	24.00	
		5		12.4033	23.6473	-194	+1.2	+1.0	40 31 38.36	+ 4	43.62	+ 32	+ 31	+10	7	22.78	74.7
		7		17.7903	19.6993	- 18	- .4	+ .2	40 37 10.50	- 48.19	- 5	- 4	- 1	6	22.27		
		8		22.9477	16.5910	- 13	- .6	- .8	40 33 42.29	+ 2	40.59	+ 19	- 20	+ 5	6	22.98	

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
July															
3	III 9	D	24.1933	10.1353	-346	-.4	-.5	40 42 18.17	- 5 54.34	- 40	- 13	-10	6	40 36 23.26	74.4
5	II 3	D	21.2487	19.7213	+ 4	-.3	+.1	40 35 44.15	+ 38.60	+ 5	- 4	+ 1	6	22.83	69.4
	4		19.8970	16.9320	- 41	-.9	-.5	40 37 37.44	- 1 14.81	- 8	- 21	- 2	7	22.39	
	5		18.8150	19.9427	- 7	-.9	-.9	40 36 51.31	- 28.48	- 3	- 26	0	9	22.63	
	6		32.2340 ^{iv}	8.4437 ⁱⁱ	+ 11	-.9	.0	40 46 25.23	-10 1.15	- 99	- 14	-18	6	22.83	68.9
	7		14.9567	27.5530	+138	-.4	-.3	40 41 41.58	- 5 18.63	- 36	- 10	- 9	6	22.46	68.1
	8		9.7807 ⁱⁱ	29.8447 ^{iv}	0	-.1	.0	40 27 55.25	+ 8 26.97	+ 89	- 1	+17	8	23.35	
	10		12.3277 ⁱⁱ	27.3910 ^{iv}	+ 6	+.6	.0	40 30 1.07	+ 6 20.63	+ 75	+ 10	+12	7	22.74	68.5
	III 1	R	29.7010	13.4353	+222	-.9	-.5	40 43 15.04	- 6 51.56	- 46	- 21	-14	10	22.77	66.6d
	2		6.9693 ⁱⁱ	31.7533 ^{iv}	- 27	-1.0	-.7	40 46 50.72	-10 26.16	-1.02	- 25	-23	11	23.17	
July	3		9.3133 ⁱⁱ	34.0423 ^{iv}	+ 69	+1.9	+.1	40 25 56.62	+10 25.02	+1.02	+ 32	+18	6	23.22	
9	4		7.5640 ⁱⁱ	32.1083 ^{iv}	- 7	-2.1	-2.0	40 26 1.84	+10 20.16	+1.02	- 58	+19	6	22.69	66.8
	III 1	D	10.9800	27.3130	-122	-.6	-.5	40 43 15.93	- 6 32.40	- 48	- 16	-14	10	22.85	59.1
	2		32.3247 ^{iv}	7.4885 ⁱⁱ	- 2	-.3	+.7	40 46 51.62	-10 27.55	-1.06	+ 4	-24	11	22.92	
	3		32.4363 ^{iv}	7.6983 ⁱⁱ	+ 3	-3.4	-3.7	40 25 57.71	+10 25.08	+1.05	-1.00	+18	6	23.08	
	4		33.0963 ^{iv}	8.5557 ⁱⁱ	+ 32	-3.1	-1.9	40 26 2.92	+10 20.16	+1.05	- 74	+19	6	23.64	
	5		15.4683	26.6553	+104	-.0	-1.7	40 31 39.95	+ 4 42.93	+ 32	- 22	+10	7	23.15	
	6		23.5057	19.5090	+ 53	.0	-1.3	40 38 4.48	- 1 41.12	- 12	- 16	- 3	6	23.11	
	7		20.2543	22.1863	+ 20	-1.5	-1.5	40 37 12.21	- 48.87	- 6	- 43	- 2	6	22.89	58.5
	8		24.9110	18.6340	+ 96	-.7	-1.0	40 33 44.04	+ 2 38.85	+ 18	- 24	+ 4	6	22.93	
	9		27.5773	13.5037	+ 67	-1.0	-1.1	40 42 19.91	- 5 55.78	- 41	- 30	-10	6	23.38	57.6
	IV 1	D	21.9233	20.6823	+ 13	+1.3	-.2	40 36 54.14	- 31.39	- 4	+ 18	- 1	13	23.01	55.8
	2		20.3993	21.0507	+ 3	-2.0	-.9	40 36 39.82	- 16.47	- 2	- 43	0	10	23.00	
	3		12.7890	29.6640	+180	-.6	-1.5	40 29 15.54	+ 7 6.85	+ 49	- 28	+13	7	22.80	56.8
	4		23.2873	18.5613	+ 39	-.9	-.4	40 38 22.34	- 1 59.51	- 14	- 20	- 4	10	22.55	
	5		13.1973 ⁱⁱ	30.6350 ^{iv}	- 42	-.8	-.5	40 29 1.91	+ 7 20.50	+ 84	- 20	+13	6	23.24	
	6		30.9527 ^{iv}	11.0743 ⁱⁱ	0	-2.0	-1.6	40 28 0.37	+ 8 22.28	+ 91	- 52	+14	5	23.23	
	7		13.5607 ⁱⁱ	29.0287 ^{iv}	- 52	-.1	-.4	40 29 50.99	+ 6 30.71	+ 79	- 6	+11	5	22.59	
	8		23.6567	13.1360	+123	-.5	-1.1	40 42 56.47	- 6 32.48	- 45	- 22	-12	7	23.27	
	9		18.3313	21.2607	- 6	-2.3	-2.8	40 37 37.09	- 1 14.00	- 9	- 72	- 2	12	22.38	
July	10		16.2430	24.8887	+ 43	-.3	.0	40 40 2.09	- 3 38.56	- 25	- 5	- 6	6	23.23	55.2
	11		5.7830 ⁱⁱ	33.9913 ^{iv}	- 9	-1.2	-.7	40 24 29.53	+11 52.74	+1.15	- 28	+20	7	23.41	55.6
	12		25.6060	14.1027	- 14	-.7	+.3	40 41 13.45	- 4 50.63	- 33	- 8	- 9	7	22.39	
10	III 1	R	29.8683	13.5290	+241	+1.1	+2.0	40 43 16.18	- 6 53.46	- 48	+ 42	-14	10	22.62	68.2
	2		8.5570 ⁱⁱ	33.3937 ^{iv}	+ 41	+.8	+.7	40 46 51.88	-10 27.67	-1.06	+ 22	-24	11	23.24	66.9
July	3		8.0050 ⁱⁱ	32.6490 ^{iv}	+ 14	+2.4	+2.3	40 25 58.02	+10 22.73	+1.05	+ 67	+18	6	22.71	
	4		8.7317 ⁱⁱ	33.2090 ^{iv}	+ 37	+.4	+.5	40 26 3.23	+10 18.58	+1.05	+ 13	+19	6	23.24	
	5		25.9337	14.7900	+ 35	-1.2	-.6	40 31 40.25	+ 4 41.66	+ 32	- 26	+10	7	22.14	65.4
11	III 1	D	12.8370	29.1720	+143	+.8	+2.3	40 43 16.44	- 6 53.11	- 48	+ 42	-14	10	23.23	73.9
12	III 1	R	29.0620	12.6997	+125	+1.0	+1.8	40 43 16.71	- 6 53.75	- 48	+ 39	-14	10	22.83	79.0
	2		9.2537 ⁱⁱ	34.1163 ^{iv}	+ 72	+1.3	+1.6	40 46 52.42	-10 28.40	-1.24	+ 40	-24	11	23.05	
	3		8.0523 ⁱⁱ	32.6987 ^{iv}	+ 16	+.3	+2.0	40 25 58.66	+10 22.80	+1.23	+ 30	+18	6	23.23	78.3
	4		9.5440 ⁱⁱ	33.9783 ^{iv}	+ 67	+.7	+.8	40 26 3.86	+10 17.57	+1.23	+ 21	+19	6	23.12	
	5		26.5570	15.4530	+ 97	+1.3	+.2	40 31 40.88	+ 4 40.82	+ 32	+ 23	+10	7	22.42	78.4
	6		17.2810	21.3700	- 24	+1.6	+1.4	40 38 5.47	- 1 43.26	- 12	+ 43	- 3	6	22.55	
	7		21.0500	19.0327	+ 1	+1.6	+.2	40 37 13.22	- 50.97	- 6	+ 28	- 2	6	22.51	
	8		15.9853	22.2247	- 49	+.6	-.1	40 33 45.06	+ 2 37.53	+ 18	+ 8	+ 4	6	22.95	78.4
	9		13.2100	27.3607	+ 34	-1.0	-.1	40 42 20.93	- 5 57.64	- 41	- 17	-10	6	22.67	
	IV 1	R	20.6610	21.9337	+ 13	-.3	-.6	40 36 54.99	- 32.19	- 4	- 12	- 1	13	22.76	77.6
	2		21.9957	21.2967	+ 9	+.2	.0	40 36 40.70	- 17.68	- 2	+ 3	0	10	23.13	
	3		28.2560	11.4143	- 25	-.7	-.2	40 29 16.46	+ 7 5.49	+ 49	- 13	+13	7	22.51	76.8
	4		17.1003	21.8880	- 21	-.1	+1.1	40 38 23.19	- 2 0.92	- 14	+ 12	- 4	10	22.31	76.8
	5		29.3623 ^{iv}	11.9830 ⁱⁱ	- 14	-.4	.0	40 29 2.78	+ 7 19.10	+1.02	- 6	+13	6	23.03	
	6		9.8267 ⁱⁱ	29.6500 ^{iv}	+ 1	+1.4	+.9	40 28 1.27	+ 8 20.89	+1.09	+ 34	+14	5	23.78	
	7		26.5987 ^{iv}	11.1633 ⁱⁱ	+ 45	-1.7	-2.3	40 29 51.87	+ 6 30.00	+ 97	- 56	+11	5	22.44	

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther- mom.
						A	B		Micrometer.	δ	l	r	Mer		
July 12	IV 8	R	11.7987	27.3700	— 57	— .6	.0	40 42 57.30	— 6 33.31	— 45	— 9	— 12	7	40 36 23.40	75.6
	9		22.4447	19.4967	+ 25	+ .1	— .2	40 37 37.82	— 1 14.55	— 9	— 1	— 2	12	23.27	
	10		24.5270	15.8483	+ 16	+ .6	.0	40 40 2.87	— 3 39.33	— 25	+ 9	— 6	6	23.38	
	11		33.5513 ^{iv}	5.4093 ⁱⁱ	— 37	— .6	— .9	40 24 30.28	+ 11 50.99	+ 1.33	— 21	+ 20	7	22.66	
	12		13.6367	25.1350	— 62	— .0	— 1.1	40 41 14.17	— 4 50.38	— 33	— 14	— 9	7	23.30	75.4
July 13	III 1	D	13.9443	30.2810	+ 290	+ .9	+ 2.1	40 43 16.96	— 6 53.52	— 48	+ 41	— 14	10	23.33	81.9
	2		30.7720 ^{iv}	5.8833 ⁱⁱ	— 72	+ .7	+ 1.6	40 46 52.69	— 10 28.70	— 1.24	+ 31	— 24	11	22.93	81.5
	3		34.2067 ^{iv}	9.5773 ⁱⁱ	+ 76	+ 1.3	+ 2.0	40 25 58.97	+ 10 22.01	+ 1.23	+ 45	+ 18	6	22.90	
	4		31.1690 ^{iv}	6.7063 ⁱⁱ	— 42	+ 1.4	.0	40 26 4.17	+ 10 18.01	+ 1.23	+ 23	+ 19	6	23.89	81.2
	5		15.1510	26.2557	+ 68	+ 1.0	+ .7	40 31 41.20	+ 4 40.76	+ 32	+ 25	+ 10	7	22.70	80.6
	6		22.3433	18.2537	+ 10	+ 2.0	+ 1.5	40 38 5.81	— 1 43.36	— 12	+ 51	— 3	6	22.87	79.6
	7		18.6077	20.6130	— 7	— .7	— .2	40 37 13.56	— 50.65	— 6	— 13	— 2	6	22.76	
	8		22.2180	16.0040	— 48	— 1.1	— 2.5	40 33 45.41	+ 2 36.89	+ 18	— 49	+ 4	6	22.09	
	9		25.9910	11.8240	— 136	.0	— .1	40 42 21.28	— 5 57.62	— 41	— 1	— 10	6	23.20	77.7
	IV 1	D	20.6493	19.3720	+ 1	+ .7	— .7	40 36 55.29	— 32.28	— 4	+ 2	— 1	13	23.11	74.3
	2		18.2353	18.9683	— 9	— 1.1	.0	40 36 41.01	— 18.50	— 2	— 17	0	10	22.42	
	3		11.3597	28.2093	— 32	+ .8	— 1.0	40 29 16.79	+ 7 5.67	+ 49	— 7	+ 13	7	23.08	74.4
	4		20.7393	15.9650	— 69	— .8	— 1.2	40 38 23.50	— 2 0.46	— 14	— 28	— 4	10	22.68	
	5		10.7817 ⁱⁱ	28.1347 ^{iv}	+ 12	— .1	— .4	40 29 3.16	+ 7 18.50	+ 1.02	— 6	+ 13	6	22.81	
	6		29.3733 ^{iv}	9.5817 ⁱⁱ	+ 1	.0	+ .2	40 28 1.60	+ 8 20.21	+ 1.09	+ 2	+ 14	5	23.11	
	7		10.6077 ⁱⁱ	26.0217 ^{iv}	+ 67	— .6	— .5	40 29 52.19	+ 6 29.64	+ 97	— 16	+ 11	5	22.80	
	8		26.4860	10.8930	— 180	— .8	— 2.3	40 42 57.61	— 6 33.54	— 45	— 34	— 12	7	23.23	72.6
	9		17.4717	20.4447	— 27	— .0	.0	40 37 33.08	— 1 15.05	— 9	0	— 2	12	23.04	72.8
	10		16.2730	24.9560	+ 45	— 1.2	— .4	40 40 3.16	— 3 39.51	— 25	— 24	— 6	6	23.16	
	11		4.7273 ⁱⁱ	32.8770 ^{iv}	— 84	+ 1.0	+ .6	40 24 30.54	+ 11 51.06	+ 1.33	+ 23	+ 20	7	23.43	
July 17	III 1	R	24.2647	12.7177	— 153	+ .1	+ 1.1	40 41 14.42	— 4 51.38	— 33	+ 15	— 9	7	22.84	71.9
	2		27.7167	11.3427	— 68	— 2.4	— 1.3	40 43 17.81	— 6 53.56	— 48	— 55	— 14	10	23.18	75.4
	3		10.1883 ⁱⁱ	34.9863 ^{iv}	+ 108	+ .6	+ .6	40 46 53.58	— 10 29.39	— 95	+ 17	— 24	11	23.28	
	4		6.8560 ⁱⁱ	31.4447 ^{iv}	— 34	+ 1.8	+ 1.8	40 26 0.06	+ 10 21.21	+ 94	+ 51	+ 18	6	22.96	75.1
	5		6.7910 ⁱⁱ	31.2030 ^{iv}	— 38	+ .6	.0	40 26 5.26	+ 10 16.74	+ 94	+ 10	+ 19	6	23.29	
	6		26.0203	14.9500	+ 47	— .5	— .5	40 31 42.29	+ 4 39.84	+ 32	— 14	+ 10	7	22.48	
	7		16.7203	20.8430	— 44	— .7	.0	40 38 7.00	— 1 44.06	— 12	— 11	— 3	6	22.74	74.5
	8		19.3943	17.3293	— 30	+ 1.1	.0	40 37 14.78	— 52.10	— 6	+ 18	— 2	6	22.84	
	9		16.4527	22.6280	— 26	+ .6	+ .9	40 33 46.66	+ 2 35.97	+ 18	+ 21	+ 4	6	23.12	
	10		12.8570	27.0730	— 5	— .9	+ .2	40 42 22.55	— 5 59.19	— 41	— 12	— 10	6	22.79	74.3
	IV 1	R	19.6857	21.0093	+ 3	— .8	— .4	40 36 56.46	— 33.45	— 4	— 18	— 1	13	22.91	69.6
	2		22.1360	21.3803	+ 11	+ 1.0	+ 1.4	40 36 42.21	— 19.12	— 2	— 33	0	10	22.84	
	3		28.2407 ^{iv}	10.9177 ⁱⁱ	+ 10	— .9	.0	40 29 4.47	+ 7 17.74	+ 73	— 14	+ 13	6	22.99	
July 24	III 1	D	8.6123 ⁱⁱ	28.3640 ^{iv}	+ 4	.0	— .5	40 28 2.89	+ 8 19.09	+ 80	— 6	+ 14	5	22.91	<i>d</i>
	2		11.8107	28.2277	+ 3	— 1.7	— .7	40 43 19.15	— 6 54.83	— 48	— 36	— 14	10	23.44	70.0
	3		30.7277 ^{iv}	5.8230 ⁱⁱ	— 75	+ 1.6	+ .4	40 46 54.97	— 10 29.09	— 95	+ 30	— 24	11	[25.10]	*
	4		32.1230 ^{iv}	7.5753 ⁱⁱ	+ 4	— 1.8	— .4	40 26 1.78	+ 10 20.27	+ 94	— 34	+ 18	6	22.89	70.0
	5		30.9720 ^{iv}	6.6027 ⁱⁱ	— 49	— .6	— 1.2	40 26 6.97	+ 10 15.63	+ 94	— 24	+ 19	6	23.55	
	6		13.2130	24.2530	— 121	+ .8	— .4	40 31 44.00	+ 4 38.65	+ 32	+ 8	+ 10	7	23.22	69.4
	7		23.8653	19.6937	+ 65	+ .1	— 8	40 38 8.87	— 1 45.57	— 12	— 8	— 3	6	23.13	
	8		18.2437	20.3580	— 13	— 1.8	— 1.9	40 37 16.70	— 53.39	— 6	— 53	— 2	6	22.76	
	9		22.3500	16.2463	— 37	— .4	— .5	40 33 48.62	+ 2 34.13	+ 18	— 13	+ 4	6	22.90	
	10		27.5530	13.2797	+ 52	+ .5	— .3	40 42 24.52	— 6 0.78	— 41	+ 4	— 10	6	23.33	69.4 <i>d</i>
	11		20.4553	19.0700	— 2	+ .2	.0	40 36 58.21	— 35.00	— 4	+ 3	— 1	13	23.32	69.0
	12		19.4613	20.2727	— 1	— 2.0	— 2.9	40 36 44.04	— 20.50	— 2	— 69	— 0	10	22.93	
	13		11.1803	27.8907	— 67	+ .5	— 1.4	40 29 20.06	+ 7 2.06	+ 49	— 10	+ 13	7	22.71	
	14		23.2290	18.3397	+ 33	— 1.2	— .2	40 38 26.55	— 2 3.62	— 14	— 21	— 4	10	22.64	68.9
	15		12.6303 ⁱⁱ	30.8740 ^{iv}	— 27	+ .4	+ .2	40 29 6.48	+ 7 15.64	+ 73	+ 9	+ 13	6	23.13	
	16		27.4970 ^{iv}	12.1737 ⁱⁱ	+ 7	— 2.8	— 2.4	40 29 55.44	+ 6 27.20	+ 68	— 74	+ 11	5	22.74	
	17		11.0683	26.7820	— 147	+ .2	+ .7	40 43 0.72	— 6 36.68	— 45	+ 12	— 12	7	23.66	

* Instrument probably disturbed.

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
July 24	IV 9	D	22.3747	19.3193	+ 22	— .4	— .9	40 37 40.81	— 1 17.26	— 9	— 18	— 2	12	40 36 23.38	68.4
	10		23.9843	15.1797	— 32	+1.4	+ .1	40 40 6.18	— 3 42.39	— 25	+ 24	— 6	6	23.78	
	11		34.6077 ^{iv}	6.5943 ⁱⁱ	+ 42	— .2	.0	40 24 33.44	+11 47.94	+1.04	— 3	+20	7	22.66	
July 25	12		13.5547	25.1597	— 75	— .8	— .8	40 41 17.21	— 4 53.04	— 33	— 23	— 9	7	23.59	68.5
	III 1	R	26.8570	10.3860	—199	+ .7	+ .2	40 43 19.38	— 6 55.68	— 48	+ 13	—14	10	23.31	78.0
	2		8.5287 ⁱⁱ	33.4850 ^{iv}	+ 43	+1.6	+1.1	40 46 55.22	—10 30.69	— 95	+ 40	—24	11	23.85	77.7
	3		8.6337 ⁱⁱ	33.1263 ^{iv}	+ 35	+2.3	+1.6	40 26 2.06	+10 18.96	+ 94	+ 56	+18	6	22.76	77.8
	4		6.7493 ⁱⁱ	31.1077 ^{iv}	— 42	—1.4	—2.0	40 26 7.26	+10 15.37	+ 94	— 47	+19	6	23.35	
	5		26.2387	15.2370	+ 71	+ .4	+ .7	40 31 44.29	+ 4 38.17	+ 32	+ 15	+10	7	23.10	77.4
	6		17.3733	21.5553	— 20	—1.5	— .4	40 38 9.18	— 1 45.62	— 12	— 29	— 3	6	23.18	
	7		20.9457	18.8147	— 3	+1.6	+ .4	40 37 17.01	— 53.84	— 6	+ 30	— 2	6	23.45	
	8		17.1653	23.2457	+ 11	— .8	—1.2	40 33 48.96	+ 2 33.66	+ 18	— 28	+ 4	6	22.62	
	9		14.3500	28.6027	+184	—1.0	—1.4	40 42 24.85	— 6 0.60	— 41	— 33	—10	6	23.47	75.3
	IV 1	R	19.9830	21.3907	+ 9	+ .4	+ .6	40 36 58.50	— 35.59	— 4	+ 14	— 1	13	23.13	72.1a
	2		21.7800	20.9513	+ 10	—2.2	—1.4	40 36 44.34	— 20.96	— 2	— 52	0	10	22.94	
	3		29.5227	12.8573	+174	—1.0	—1.2	40 29 20.38	+ 7 1.53	+ 49	— 31	+13	7	22.29	
	4		19.4510	24.3350	+ 81	—1.5	— .8	40 38 26.85	— 2 3.61	— 14	— 34	— 4	10	22.82	
	5		28.4383 ^{iv}	11.2143 ⁱⁱ	+ 3	— .7	— .4	40 29 6.81	+ 7 15.22	+ 73	— 16	+13	6	22.79	72.4
	6		9.9673 ⁱⁱ	29.6180 ^{iv}	— 2	+1.6	+ .4	40 28 5.21	+ 8 16.52	+ 80	+ 30	+14	5	23.02	
	7		28.0500 ^{iv}	12.7507 ⁱⁱ	— 18	—1.2	—1.6	40 29 55.76	+ 6 26.53	+ 68	— 39	+11	5	22.74	72.1
	8		12.9960	28.6840	+117	—1.5	—1.6	40 43 0.49	— 6 36.69	— 45	— 44	—12	7	22.86	
	9		24.2690	21.2307	+ 73	— .8	—1.5	40 37 41.07	— 1 16.95	— 9	— 32	— 2	12	23.81	
	10		24.5113	15.7043	+ 8	+ .1	— .2	40 40 6.47	— 3 42.55	— 25	— 1	— 6	6	23.66	
	11		35.0247 ^{iv}	7.0310 ⁱⁱ	+ 72	—1.0	—1.3	40 24 33.72	+11 47.52	+1.04	— 33	+20	7	[22.22]	*
	12		15.0113	26.6280	+ 83	— .4	— .5	40 41 17.47	— 4 53.74	— 33	— 13	— 9	7	23.25	71.8
Aug. 5	III 1	D	15.9573	32.4590	—606	—1.2	—1.0	40 43 21.20	— 6 58.73	+ 17	— 32	—14	9	22.27	67.7†
	2		32.3293 ^{iv}	7.3310 ⁱⁱ	— 8	— .8	—1.7	40 46 57.18	—10 31.99	—1.28	— 34	—25	11	23.43	66.3
	3		34.9670 ^{iv}	10.5520 ⁱⁱ	+106	—1.9	— .9	40 26 4.53	+10 17.54	+1.29	— 42	+18	5	23.17	
	4		33.5277 ^{iv}	9.3250 ⁱⁱ	+ 52	— .4	— .2	40 26 9.74	+10 12.03	+1.29	— 7	+18	6	23.23	
	5		14.9977	25.9073	+ 43	+ .8	+ .6	40 31 46.83	+ 4 35.93	— 11	+ 20	+ 9	7	23.01	65.8
	6		23.2123	18.8963	+ 40	— .2	— .8	40 38 12.00	— 1 49.22	+ 4	— 13	— 3	6	22.72	
	7		18.2310	20.4863	— 12	— .5	— .9	40 37 19.94	— 56.99	+ 2	— 19	— 2	6	22.82	
	8		23.8857	17.9057	+ 47	—1.6	—1.0	40 33 51.98	+ 2 31.31	— 6	— 38	+ 4	6	22.95	
	9		26.2977	11.8497	—116	—1.1	—1.6	40 42 27.93	— 6 4.99	+ 15	— 38	—10	5	22.66	64.0
	IV 1	D	20.1497	18.6177	— 8	+2.4	.0	40 37 1.55	— 38.71	+ 2	+ 39	— 1	13	23.37	60.9
	2		18.4500	19.4040	— 9	—2.4	—2.3	40 36 47.52	— 24.10	+ 1	— 68	— 1	11	22.85	
	3		11.7290	28.3297	+ 19	— .7	—1.8	40 29 23.83	+ 6 59.75	— 16	— 34	+13	7	23.28	
	4		21.8590	16.8027	— 30	+ .4	.0	40 38 30.10	— 2 7.76	+ 5	+ 6	— 4	10	22.51	61.0
	5		11.2040 ⁱⁱ	28.2767 ^{iv}	+ 7	— .6	—2.3	40 29 10.38	+ 7 11.65	+1.36	— 38	+12	6	23.19	61.1
	6		29.8230 ^{iv}	10.3120 ⁱⁱ	0	—2.1	—1.8	40 28 8.77	+ 8 13.28	+1.34	— 56	+13	5	23.01	
	7		11.4410 ⁱⁱ	26.5513 ^{iv}	+ 43	+ .4	—1.1	40 29 59.30	+ 6 22.13	+1.38	— 7	+11	6	22.91	
	8		26.1637	10.2742	—225	+ .1	— .6	40 43 4.42	— 6 41.15	+ 16	— 6	—12	7	23.32	60.9
	9		17.4260	20.6137	— 28	—2.4	—2.4	40 37 44.09	— 1 20.27	+ 3	— 69	— 2	11	23.25	
	10		15.5473	24.5003	+ 2	—2.0	—1.3	40 40 9.84	— 3 46.36	+ 9	— 49	— 6	6	23.08	60.2
	11		6.7920 ⁱⁱ	34.6993 ^{iv}	+ 51	—1.5	—1.5	40 24 36.98	+11 45.69	+1.25	— 43	+21	6	23.76	
Aug. 6	12		25.6910	13.8953	— 21	— .1	+ .1	40 41 20.64	— 4 58.17	+ 12	— 0	— 9	7	22.57	60.3
	III 1	R	29.0530	12.4807	+110	.0	+1.3	40 43 21.43	— 6 59.26	+ 17	+ 16	—15	9	22.44	69.0
	2		9.1623 ⁱⁱ	34.2177 ^{iv}	+ 75	+1.3	+2.6	40 46 57.16	—10 33.65	—1.28	+ 54	—24	11	22.64	
	3		7.7030 ⁱⁱ	32.0973 ^{iv}	— 5	+1.4	+ .3	40 26 4.81	+10 16.73	+1.29	+ 26	+18	5	23.32	
	4		9.1787 ⁱⁱ	33.3690 ^{iv}	+ 47	+ .4	.0	40 26 9.97	+10 11.71	+1.29	+ 6	+18	6	23.27	
	5		26.5083	15.6217	+100	— .4	+ .9	40 31 47.07	+ 4 35.49	— 11	+ 5	+ 9	7	22.66	69.4
	6		18.0220	22.3563	+ 8	—1.3	— .2	40 38 12.26	— 1 49.60	+ 4	— 23	— 3	6	22.50	69.8
	7		20.7910	18.4823	+ 8	+1.4	+ .9	40 37 20.20	— 58.35	+ 2	+ 34	— 2	6	22.25	
	8		17.7787	23.7367	+ 40	— .9	— .6	40 33 52.25	+ 2 30.73	— 6	— 22	+ 4	6	22.80	
	9		12.7277	27.1853	— 3	—2.0	— .9	40 42 28.21	— 6 5.51	+ 15	— 44	—10	5	22.36	69.1

* Probably bisected with thread V by mistake. † Outside micrometer limit.

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
Aug. 6	IV 1	R	19.5837	21.1100	+ 3	-1.7	-1.7	40 37 1.81	- 38.60	+ 2	- 49	- 1	13	40 36 22.86	65.2
			25.0143	24.0433	+ 37	-1.6	-1.6	40 36 47.79	- 24.64	+ 1	- 46	- 1	11	22.80	
			27.9357	11.3527	- 52	-1.7	- .9	40 29 24.13	+ 6 59.12	- 16	- 39	+13	7	22.90	
			18.7967	23.8440	+ 58	-1.2	-1.0	40 38 30.37	- 2 7.75	+ 5	- 32	- 4	10	22.41	64.4
			28.0920 ^{iv}	11.0807 ⁱⁱ	+ 12	+ .6	+ .4	40 29 10.68	+ 7 10.12	+1.36	+ 15	+12	6	22.49	
			9.1027 ⁱⁱ	28.5907 ^{iv}	+ 5	.0	- .4	40 28 9.07	+ 8 12.71	+1.34	- 5	+13	5	23.25	
			27.0347 ^{iv}	11.9453 ⁱⁱ	+ 22	- .3	+ .8	40 29 59.60	+ 6 21.55	+1.38	+ 5	+11	6	22.75	
			12.4307	28.3037	+ 50	- .7	- .4	40 43 4.70	- 6 41.43	+ 16	- 16	-12	7	23.22	
			21.7927	18.5610	- 4	- .4	+ .8	40 37 44.34	- 1 21.69	+ 3	+ 3	- 2	11	22.80	64.6
			24.2853	15.2787	- 22	+ .8	- .6	40 40 10.13	- 3 47.67	+ 9	+ 5	- 6	6	22.60	63.9
Aug. 9	III 1	D	33.2097 ^{iv}	5.3243 ⁱⁱ	- 51	-1.6	- .5	40 24 37.25	+11 44.88	+1.25	- 32	+21	6	23.33	
			14.5050	26.3290	+ 43	+ .5	+ .9	40 41 20.89	- 4 59.04	+ 12	+ 20	- 9	6	22.14	72.0
			13.2903	29.8677	+226	- .3	+1.0	40 43 21.93	- 6 59.69	+ 17	+ 7	-15	9	22.42	
			30.9057 ^{iv}	5.8177 ⁱⁱ	- 74	+1.5	+1.3	40 46 57.97	-10 34.10	-1.28	+ 40	-24	11	22.86	71.2
			32.5387 ^{iv}	8.1757 ⁱⁱ	+ 14	- .2	+1.7	40 26 5.48	+10 15.99	+1.29	+ 18	+18	5	23.17	
			32.4537 ^{iv}	8.2793 ⁱⁱ	+ 14	+1.2	+2.0	40 26 10.70	+10 11.22	+1.29	+ 45	+18	6	23.90	
			14.5917	25.4540	+ 3	+ .7	+ .1	40 31 47.82	+ 4 34.63	- 11	+ 13	+ 9	7	22.63	70.4
			22.0567	17.6593	- 8	+2.6	+1.3	40 38 13.09	- 1 51.16	+ 4	+ 52	- 3	6	22.58	
			18.6363	20.9653	- 7	+1.3	+1.7	40 37 21.06	- 58.86	+ 2	+ 48	- 2	6	22.68	
			22.4127	16.5063	- 29	+2.7	+2.1	40 33 53.13	+ 2 29.25	- 6	+ 70	+ 4	6	23.12	
Aug. 10	IV 1	D	25.9370	11.4433	-104	+ .2	-1.3	40 42 29.07	- 6 6.02	+ 15	- 13	-10	5	23.02	70.2
			20.1017	18.5273	- 10	+1.5	+ .9	40 37 2.67	- 39.78	+ 2	+ 35	- 1	13	23.38	65.6
			19.1140	20.1817	- 3	+1.5	+1.7	40 36 48.68	- 26.99	+ 1	+ 45	- 9	11	22.17	65.7
			11.6737	28.2053	- 11	+1.0	-2.2	40 29 25.09	+ 6 57.93	- 16	- 11	+13	7	22.95	
			21.4637	16.3267	- 51	+2.0	+1.5	40 38 31.28	- 2 9.75	+ 5	+ 51	- 4	10	22.15	
			11.4110 ⁱⁱ	28.3890 ^{iv}	+ 4	+ .3	+ .4	40 29 11.67	+ 7 9.25	+1.36	+ 10	+12	6	22.56	
			30.7027 ^{iv}	10.2720 ⁱⁱ	+ 2	- .6	- .2	40 28 10.06	+ 8 11.26	+1.34	- 12	+13	5	22.72	64.1
			13.3893 ⁱⁱ	28.4150 ^{iv}	- 40	+1.7	+1.7	40 30 0.58	+ 6 19.78	+1.38	+ 49	+11	6	22.40	
			27.5413	11.5790	- 60	+2.4	+1.2	40 43 5.64	- 6 43.41	+ 16	+ 54	-12	7	22.88	
			18.3020	21.5840	- 3	+ .6	+ .8	40 37 45.17	- 1 22.97	+ 3	+ 19	- 2	11	22.51	63.9
Aug. 10	III 1	R	15.7183	24.7423	+ 17	-1.5	- .7	40 40 11.05	- 3 48.19	+ 9	- 33	- 6	6	22.62	
			5.1763 ⁱⁱ	33.0077 ^{iv}	- 62	- .3	- .5	40 24 38.13	+11 43.49	+1.25	- 11	+21	-6	23.03	
			23.7743	11.9157	-224	- .7	- .9	40 41 21.75	- 4 59.25	+ 12	- 23	- 9	7	22.37	64.4
			27.7503	11.1680	- 78	-1.0	-1.1	40 43 22.10	- 6 59.04	+ 17	- 30	-15	9	22.87	67.5
			8.5830 ⁱⁱ	33.6800 ^{iv}	+ 52	+1.7	+1.4	40 46 58.16	-10 34.64	-1.28	+ 45	-24	11	22.56	67.2
			7.4670 ⁱⁱ	31.8207 ^{iv}	- 16	+2.3	+3.7	40 26 5.71	+10 15.68	+1.29	+ 83	+18	5	23.74	68.6
			7.5190 ⁱⁱ	31.6727 ^{iv}	- 15	+3.4	+1.9	40 26 10.93	+10 10.62	+1.29	+ 78	+18	6	23.86	
			25.9263	15.0437	+ 46	-2.6	-1.2	40 31 48.07	+ 4 35.25	- 11	- 57	+ 9	7	22.80	67.0
			18.6507	23.0067	+ 31	-2.0	-1.2	40 38 13.35	- 1 50.21	+ 4	- 47	- 3	6	22.74	65.1
			21.2137	18.9210	0	-2.2	-2.7	40 37 21.33	- 57.96	+ 2	- 69	- 2	6	22.74	
Aug. 20	IV 1	R	17.0610	22.9917	0	-1.4	-1.8	40 33 53.42	+ 2 29.94	- 6	- 45	+ 4	6	22.95	
			13.6693	28.1710	+116	+ .2	+2.0	40 42 29.40	- 6 6.93	+ 15	+ 28	-10	5	22.85	65.0
			20.2323	21.8077	- 13	- .6	.0	40 37 2.97	- 39.86	+ 2	- 9	- 1	13	23.16	62.1
			22.4353	21.4093	- 15	-2.2	-2.0	40 36 49.00	- 25.90	+ 1	- 60	- 1	11	22.61	
			28.0990	11.5813	- 22	+ .3	.0	40 29 25.44	+ 6 57.55	- 16	+ 5	+13	7	23.08	62.5
			18.2380	23.3487	+ 36	-1.8	+ .2	40 38 31.60	- 2 9.30	+ 5	- 26	- 4	10	22.15	
			28.2227 ^{iv}	11.2680 ⁱⁱ	+ 8	+ .5	+1.5	40 29 12.02	+ 7 8.67	+1.36	+ 27	+12	6	22.50	
			26.8863 ^{iv}	11.8420 ⁱⁱ	+ 28	-1.8	- .8	40 30 0.92	+ 6 20.43	+1.38	- 39	+11	5	22.50	61.7
			13.0463	28.9827	+132	-1.2	- .3	40 43 5.97	- 6 43.24	+ 16	- 23	-12	7	22.61	62.0
			21.7623	18.5030	+ 3	- .2	- .6	40 37 45.47	- 1 22.41	+ 3	- 10	- 2	11	23.08	
Aug. 20	III 2	D	24.1673	15.1137	- 28	+2.6	+1.2	40 40 11.38	- 3 48.83	+ 9	+ 57	- 6	6	23.21	61.6
			34.4823 ^{iv}	6.6900 ⁱⁱ	+ 41	+1.2	+3.1	40 24 38.45	+11 42.76	+1.25	+ 58	+21	6	23.31	62.0
			13.8933	25.7413	- 20	- .9	- .7	40 41 22.06	- 4 59.49	+ 12	- 23	- 9	7	22.44	
			32.1530 ^{iv}	7.0097 ⁱⁱ	- 19	+1.1	+1.1	40 46 59.41	-10 35.63	-1.28	+ 32	-24	11	22.69	68.8
			32.3123 ^{iv}	8.0093 ⁱⁱ	+ 6	-1.1	- .8	40 26 7.35	+10 14.45	+1.29	- 28	+18	5	23.04	

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
Aug. 20	III 5	D	14.2933	25.0670	-30	+1.3	+1.5	40 31 49.82	+ 4 32.81	- 11	+ 40	+ 9	7	40 46' 22.58	69.1
			21.8910	17.4120	-14	+2.8	+1.9	40 38 14.93	- 1 53.20	+ 4	+ 69	- 3	6	22.49	
			18.5790	21.9957	+ 8	+2.0	+2.1	40 37 23.45	- 1 1.12	+ 2	+ 59	- 2	6	22.98	
			23.0963	17.2647	+ 9	+ .1	- .1	40 33 55.65	+ 2 27.46	- 6	- 0	+ 4	6	23.15	68.8
			27.8607	12.7880	+ 11	.0	-1.0	40 42 31.70	- 6 8.46	+ 15	- 8	-10	5	23.26	
	IV 1	D	19.8037	18.1190	-15	-.8	-.6	40 37 5.44	- 42.56	+ 2	- 20	- 1	13	22.82	65.1
			18.7097	19.8210	- 7	-4.0	-4.4	40 36 51.60	- 28.08	+ 1	-1.21	- 1	11	22.42	65.1
			9.9943	26.4390	-253	-.6	-1.6	40 29 28.31	+ 6 55.12	- 16	- 29	+13	7	23.18	
			21.0033	15.7903	-74	-1.2	-1.5	40 38 34.31	- 2 11.61	+ 5	- 39	- 4	10	22.42	
			11.1953 ⁱⁱ	28.0667 ^{iv}	+ 11	-.8	-.1	40 29 15.04	+ 7 6.58	+1.36	- 14	+12	6	23.02	
	6		28.8227 ^{iv}	9.4947 ⁱⁱ	+ 4	-2.4	-1.8	40 28 13.47	+ 8 8.67	+1.34	- 61	+13	5	23.05	64.9
			11.8333 ⁱⁱ	26.7490 ^{iv}	+ 34	+ .5	-.2	40 30 3.97	+ 6 17.19	+1.38	+ 5	+11	6	22.76	
			26 6020	10.5203	-201	+ .7	+ .8	40 43 8.92	- 6 46.07	+ 16	+ 21	-12	7	23.17	
			17.5217	20.8960	+ 36	+ .7	-.4	40 37 48.08	- 1 25.25	+ 3	+ 6	- 2	11	23.01	
			15.4743	24.6667	+ 5	+ .1	+ .5	40 40 14.36	- 3 52.42	+ 9	+ 8	- 6	6	22.11	63.7
Aug. 21	III 1	R	5.8883 ⁱⁱ	33.0940 ^{iv}	- 51	+2.3	+1.8	40 24 41.84	+11 40.33	+1.25	+ 59	+21	6	23.78	
			25.3800	13.3847	- 65	+ .9	+ .2	40 41 24.88	- 5 3.10	+ 12	+ 17	- 9	7	22.05	64.1
			28.1383	11.4787	- 28	+ .6	+1.1	40 43 23.34	- 7 1 12	+ 17	+ 23	-15	9	22.56	65.8
			8.4330 ⁱⁱ	33.5760 ^{iv}	+ 45	+ .7	+ .6	40 46 59.57	-10 35.79	-1.28	+ 19	-24	11	22.56	
			7.3380 ⁱⁱ	31.6303 ^{iv}	- 21	+1.9	+1.6	40 26 7.54	+10 14.11	+1.29	+ 50	+18	5	23.67	65.1
	4		8.3317 ⁱⁱ	32.4220 ^{iv}	+ 14	-.9	-2.2	40 26 12.79	+10 9.09	+1.29	- 42	+18	6	22.99	
			26.8327	16.0437	+135	-1.5	-.7	40 31 50.03	+ 4 33.11	- 11	- 33	+ 9	7	22.86	61.7
			18 4393	22.8666	+ 24	-3.2	-2.8	40 38 15.59	- 1 51.99	+ 4	- 87	- 3	6	22.80	
			21.7157	19.3160	+ 9	.0	+1.2	40 37 23.68	- 1 0.69	+ 2	+ 15	- 2	6	23.20	60.7
			17.6883	23.5060	+ 32	-1.8	-.6	40 33 55.89	+ 2 27.17	- 6	- 36	+ 4	6	22.74	
	9	D	13.3310	27.9343	+ 92	-.8	+ .7	40 42 31.95	- 6 9.44	+ 15	- 4	-10	5	22.57	61.1
			12.5590	29.1960	+125	+ .7	+2.3	40 43 23.48	- 7 0.94	+ 17	+ 40	-14	9	23.06	67.8
			30.6030 ^{iv}	5.4393 ⁱⁱ	- 90	+1.5	+ .8	40 46 59.73	-10 36.20	-1.28	+ 34	-25	11	22.45	67.0
			32.5860 ^{iv}	8.3010 ⁱⁱ	+ 17	-1.5	-1.9	40 26 7.73	+10 14.02	+1.29	- 48	+18	5	22.79	
			30.8083 ^{iv}	6.7087 ⁱⁱ	- 46	+2.0	+1.1	40 26 12.91	+10 9.18	+1.29	+ 46	+18	6	24.08	
	5		15.3690	26.1620	+ 73	-.6	-1.3	40 31 50.24	+ 4 33.06	- 11	- 26	+ 9	7	23.09	66.4
			22.8587	18.3827	+ 24	+1.5	-.1	40 38 15.82	- 1 53.22	+ 4	+ 22	- 3	6	22.89	65.8
			19.1793	21.6013	+ 7	+ .2	-.4	40 37 23.93	- 1 1.25	+ 2	- 2	- 2	6	22.72	66.4
			24.2670	18.4723	+ 72	+1.0	+ .4	40 33 56.15	+ 2 26.69	- 6	+ 21	+ 4	6	23.09	
			26.7193	12.0987	- 76	+1.7	+ .5	40 42 32.21	- 6 9.45	+ 15	+ 34	-10	5	23.20	66.5
Aug. 22	IV 1	R	19.3670	21.0837	+ 3	+ .8	+ .7	40 37 5.98	- 43.41	+ 2	+ 22	- 1	13	22.93	65.0
			21.9633	20.7980	+ 14	+1.0	+ .8	40 36 52.16	- 29.50	+ 1	+ 26	- 1	11	23.03	
			28.8673	12.4997	+ 95	-.4	-.1	40 29 28.93	+ 6 54.05	- 16	- 8	+13	7	22.94	
			18.6707	23.9163	+ 59	+ .3	+ .5	40 38 34.89	- 2 12.77	+ 5	+ 11	- 4	10	22.34	
			29.5373 ^{iv}	12.6963 ⁱⁱ	- 30	-.4	+ .1	40 29 15.69	+ 7 5.70	+1.36	- 5	+12	6	22.85	64.7
	6		10.9470 ⁱⁱ	30.2057 ^{iv}	- 3	+2.9	+2.2	40 28 14.11	+ 8 6.90	+1.34	+ 74	+13	5	23.27	
			27.8127 ^{iv}	12.9177 ⁱⁱ	- 16	-.2	+ .4	40 30 4.62	+ 6 16.54	+1.38	+ 2	+11	6	22.73	
			13.0390	29.0953	+150	-.8	+ .1	40 43 9.54	- 6 46.32	+ 16	- 11	-12	7	23.22	64.1
			23.0193	19.6203	+ 37	+ .9	-.4	40 37 48.62	- 1 26.03	+ 3	+ 9	- 2	11	22.80	
			24.4920	15.2897	- 7	+2.1	+ .4	40 40 14.98	- 3 52.64	+ 9	+ 39	- 6	6	22.82	63.8
	11	D	34.9057 ^{iv}	7.2210 ⁱⁱ	+ 71	-1.6	-.2	40 24 41.94	+11 40.11	+1.25	- 23	+21	6	23.29	63.1
			15.9587	27.9050	+201	-.1	+ .8	40 41 25.46	- 5 2.54	+ 12	+ 8	- 9	7	23.10	
			28.1333	11.4700	- 26	+ .2	+1.3	40 43 23.60	- 7 1.22	+ 17	+ 19	-15	9	22.68	73.3
			8.0927 ⁱⁱ	33.2430 ^{iv}	+ 30	+2.4	+1.9	40 46 59.87	-10 35.93	-1.28	+ 63	-24	11	23.16	72.6
			7.2037 ⁱⁱ	31.4823 ^{iv}	- 26	+ .3	+1.7	40 26 7.91	+10 13.75	+1.29	+ 26	+18	5	23.44	
Aug. 23	III 1	R	7.8000 ⁱⁱ	32 8870 ^{iv}	+ 16	+ .5	-.2	40 26 13.17	+10 9.02	+1.29	+ 6	+18	6	23.78	
			27.0850	16.3300	+160	-.2	-1.5	40 31 50.44	+ 4 32.32	- 11	- 20	+ 9	7	22.61	72.0
			18.0050	22.4987	+ 11	-.4	.0	40 38 16.05	- 1 53.64	+ 4	- 6	- 3	6	22.42	
			21.8583	19.4193	+ 14	+1.1	.0	40 37 24.17	- 1 1.70	+ 2	+ 18	- 2	6	22.71	
			17.3257	23.1223	+ 10	+ .8	+ .9	40 33 56.40	+ 2 26.58	- 6	+ 25	+ 4	6	23.27	

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
Aug. 23	III IV	R D	12.4520	27.0793	-30	-1.8	+ .1	40 42 32.47	- 6 9.74	+ 15	- 27	-10	5	40 36 22.56	71.2
			19.7363	18.0113	-16	-1.1	-1.6	40 37 6.27	- 43.57	+ 2	- 38	- 1	13	22.46	66.6a
			17.6880	18.8370	-17	-3.0	-2.2	40 36 52.46	- 29.01	+ 1	- 74	- 1	11	22.82	
			12.2017	28.5707	+ 56	- .0	- .6	40 29 29.25	+ 6 54.00	- 16	- 7	+13	7	23.22	67.3a
			20.0033	14.7400	-121	+1.0	.0	40 38 35.20	- 2 12.76	+ 5	+ 16	- 4	10	22.71	
			11.7493 ⁱⁱ	28.5737 ^{iv}	- 4	- .5	- .8	40 29 16.03	+ 7 5.35	+1.36	- 18	+12	6	22.74	66.7
			30.5110 ^{iv}	11.2427 ⁱⁱ	- 4	- .6	+ .5	40 28 14.46	+ 8 7.14	+1.34	- 3	+13	5	23.09	
			12.9800 ⁱⁱ	27.8687 ^{iv}	-20	- .2	-1.5	40 30 4.96	+ 6 16.37	+1.38	- 22	+11	6	22.66	
			27.8597	11.7797	-28	- .3	-1.4	40 43 9.87	- 6 46.47	+ 16	- 22	-12	7	23.29	
			18.9597	22.3740	+ 29	- .0	+ .2	40 37 48.92	- 1 26.39	+ 3	+ 2	- 2	11	22.67	
	Aug. 24	III D	14.9030	24.0693	-39	-2.3	-1.3	40 40 15.31	- 3 51.65	+ 9	- 53	- 6	6	23.22	65.8
			26.0000	14.0007	0	+ .3	- .3	40 41 25.77	- 5 3.37	+ 12	+ 1	- 9	7	22.51	65.6
			12.8563	29.5183	+173	+1.6	+1.1	40 43 23.71	- 7 1.69	+ 17	+ 40	-15	9	22.53	74.7
			31.8997 ^{iv}	6.7180 ⁱⁱ	-33	+2.5	+2.9	40 47 0.00	-10 36.57	-1.28	+ 77	-24	11	22.79	74.4
			31.6080 ^{iv}	7.3550 ⁱⁱ	-20	- .3	+ .8	40 26 8.08	+10 13.12	+1.29	+ 5	+18	5	22.77	
			31.6063 ^{iv}	7.5380 ⁱⁱ	-17	+1.1	+1.8	40 26 13.37	+10 8.46	+1.29	+ 40	+18	6	23.76	74.1
			14.5813	25.3637	- 0	+ .4	+ .1	40 31 50.63	+ 4 32.60	- 11	+ 8	+ 9	7	23.36	
			22.3337	17.8407	+ 3	+ .9	+ .3	40 38 16.26	- 1 53.60	+ 4	+ 18	- 3	6	22.91	73.5
			18.3140	20.7673	-10	+ .5	- .1	40 37 24.40	- 1 2.00	+ 2	+ 6	- 2	6	22.52	
			23.1857	17.4027	+ 15	+ .7	+1.0	40 33 56.64	+ 2 26.25	- 6	+ 24	+ 4	6	23.17	
	IV	R	27.9497	13.3253	+ 49	+ .5	-1.1	40 42 32.72	- 6 9.86	+ 15	- 6	-10	5	22.90	72.4
			22.6253	21.4583	+ 21	-2.1	-1.7	40 36 52.76	- 29.56	+ 1	- 55	- 1	11	22.76	68.7
			30.6687	14.3540	+357	- .9	+ .2	40 29 29.59	+ 6 53.38	- 16	- 12	+13	7	22.89	
			18.2820	23.5193	+ 42	- .6	- .8	40 38 35.51	- 2 12.52	+ 5	- 20	- 4	10	22.90	
			28.0990 ^{iv}	11.2923 ⁱⁱ	+ 11	-1.4	- .7	40 29 16.37	+ 7 4.94	+1.36	- 31	+12	6	22.54	68.1
			9.9420 ⁱⁱ	29.1893 ^{iv}	+ 3	+1.2	+ .1	40 28 14.81	+ 8 6.62	+1.34	+ 21	+13	5	23.16	
			27.1663 ^{iv}	12.2910 ⁱⁱ	+ 12	- .4	- .0	40 30 5.30	+ 6 16.11	+1.38	- 6	+11	6	22.90	
			13.0170	29.0863	+148	- .7	- .8	40 43 10.21	- 6 46.64	+ 16	- 22	-12	7	23.46	
			22.2937	18.8837	+ 18	.0	- .5	40 37 49.23	- 1 26.13	+ 3	- 6	- 6	11	23.12	68.2
			23.8577	14.6477	- 60	+ .4	- .4	40 40 15.65	- 3 52.70	+ 9	+ 1	- 6	6	23.05	67.4
Aug. 31	III	R	35.2723 ^{iv}	7.6217 ⁱⁱ	+ 97	- .8	- .6	40 24 42.59	+11 39.32	+1.25	- 20	+20	6	23.22	
			14.2130	26.2167	+ 21	- .5	- .7	40 41 26.10	- 5 3.53	+ 12	- 17	- 9	7	22.50	67.6
			27.7403	11.0697	-85	- .2	- .2	40 43 24.07	- 7 1.26	+ 17	- 6	-15	9	22.86	67.5
			8.4453 ⁱⁱ	33.6010 ^{iv}	+ 47	+ .1	- .6	40 47 0.51	-10 36.11	-1.28	- 6	-24	11	22.93	
			7.0267 ⁱⁱ	31.2607 ^{iv}	-33	+1.0	+ .8	40 26 8.81	+10 12.61	+1.29	+ 26	+18	6	23.21	66.6
			7.8543 ⁱⁱ	31.8903 ^{iv}	- 6	- .5	.0	40 26 14.15	+10 7.67	+1.29	- 8	+18	6	23.27	
			25.5117	14.7747	+ 13	- .3	- .4	40 31 51.31	+ 4 31.49	- 11	- 10	+ 9	7	22.75	65.8
			18.0173	22.5273	+ 11	-2.2	- .8	40 38 17.32	- 1 54.05	+ 4	- 45	- 3	6	22.89	
			21.6737	19.1957	+ 9	+ .4	- .3	40 37 25.55	- 1 2.67	+ 2	+ 2	- 2	6	22.96	
			18.0467	23.7863	+ 47	-1.1	- .1	40 33 57.88	+ 2 25.23	- 6	- 19	+ 4	6	22.96	
	IV	D	11.2697	25.9717	-176	-1.5	+ .3	40 42 34.04	- 6 11.26	+ 15	- 20	-10	5	22.68	65.0
			19.9543	18.1503	-15	+2.5	+1.3	40 37 8.21	- 45 57	+ 2	+ 57	- 2	14	23.35	63.4
			25.6217	26.8560	+ 67	-1.8	- .2	40 36 54.51	- 31.38	+ 1	- 31	- 1	11	22.93	64.1
			10.6157	26.9010	-178	+1.5	+ .3	40 29 31.55	+ 6 51.28	- 16	+ 27	+13	7	23.14	
			21.8007	16.4523	- 41	+2.3	+ .5	40 38 37.39	- 2 15.12	+ 5	+ 45	- 4	10	22.83	
			10.9693 ⁱⁱ	27.6527 ^{iv}	+ 20	+2.2	+1.1	40 29 18.48	+ 7 1.85	+1.36	+ 49	+12	6	22.36	62.6
			29.3487 ^{iv}	10.1833 ⁱⁱ	+ 1	-1.6	- .8	40 28 16.96	+ 8 4.55	+1.34	- 36	+13	5	22.67	
			13.8613 ⁱⁱ	28.6527 ^{iv}	- 59	+ .8	+ .9	40 30 7.47	+ 6 13.81	+1.38	+ 24	+11	6	23.07	
			27.8860	11.6933	-30	+1.4	+ .1	40 43 12.32	- 6 49.31	+ 16	+ 24	-12	7	23.36	
			18.9963	22.4960	+ 24	+1.2	+ .6	40 37 51.12	- 1 28.54	+ 3	+ 27	- 2	11	22.97	
Sep. 7	III	D	15.5987	24.8900	+ 19	- .3	+ .5	40 40 17.84	- 3 54.95	+ 9	+ 1	- 6	6	22.99	62.0
			6.1707 ⁱⁱ	33.7533 ^{iv}	- 2	+ .1	- .3	40 24 44.73	+11 37.35	+1.25	- 2	+21	6	23.58	
			25.7873	13.6817	-29	- .1	+ .1	40 41 28.20	- 5 5.98	+ 12	- 0	- 9	7	22.32	62.3
			13.9473	30.6133	+332	+ .7	+2.5	40 43 24.58	- 7 2.19	+ 17	+ 43	-15	9	22.93	70.8
			32.4870 ^{iv}	7.2417 ⁱⁱ	- 7	+ .3	+ .2	40 47 1.17	-10 36.98	-1.28	+ 7	-24	11	22.85	

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
Sep. 7	III 3	D	30.7803 ^{iv}	6.5717 ⁱⁱ	-50	-.6	-.5	40 26 9.66	+10 11.92	+1.20	-16	+17	5	22.84	71.0
			11.9290	22.6340	-254	+1.1	+.2	40 31 52.50	+4 30.00	-11	+20	+9	7	22.75	
			22.7270	18.1880	+15	+1.2	+1.1	40 38 18.46	-1 56.06	+4	+33	-3	6	22.80	71.1
			18.4030	20.9327	-8	-1.3	-.6	40 37 26.78	-1 3.94	+2	-28	-2	6	22.62	
			22.8053	17.1180	-2	+.1	+.5	40 33 59.19	+2 23.78	-6	+8	+4	6	23.09	
Sep. 11	III 1	R	26.8513	12.1027	-68	+.7	-.3	40 42 35.42	-6 12.71	+15	+7	-11	5	22.87	71.0
			28.1467	11.4837	-27	-2.3	-1.9	40 43 24.61	-7 1.21	+17	-61	-15	9	22.90	64.8
			7.8913 ⁱⁱ	33.0983 ^{iv}	+23	-.4	.0	40 47 1.29	-10 37.35	-1.19	-6	-25	11	22.55	
			8.3240 ⁱⁱ	32.5363 ^{iv}	+15	-.3	-.4	40 26 9.88	+10 12.18	+1.20	-10	+17	5	23.38	63.9
			8.7213 ⁱⁱ	32.7473 ^{iv}	+26	-2.0	-2.2	40 26 15.25	+10 7.50	+1.20	-60	+18	6	23.59	
			26.4003	15.7207	+98	-1.2	-.5	40 31 52.83	+4 30.25	-11	-26	+9	7	22.87	62.6
			18.1220	22.7227	+17	+.6	+1.7	40 38 18.87	-1 56.36	+4	+31	-3	6	22.89	
			21.0457	18.5020	-6	-1.4	-1.5	40 37 27.26	-1 4.30	+2	-41	-2	6	22.61	61.5
			16.8167	22.4777	-18	-1.4	-.8	40 33 59.72	+2 23.08	-6	-22	+4	6	22.62	61.5
			13.3840	28.1737	+103	+1.6	+3.2	40 42 36.01	-6 14.18	+15	+66	-10	5	22.59	
	IV 1	R	19.5327	21.1143	+2	.0	.0	40 37 10.72	-47.58	+2	0	-2	13	23.27	57.8
			21.3173	19.9573	+6	-.1	.0	40 36 57.18	-34.40	+1	-1	-1	11	22.88	
			29.3133	13.1633	+175	-1.1	-.4	40 29 34.53	+6 48.88	-16	-23	+13	7	23.22	58.2
			17.8467	23.2963	+28	-.1	-.2	40 38 40.23	-2 17.85	+5	-4	-5	10	22.44	
			28.0847 ^{iv}	11.4720 ⁱⁱ	+7	-.7	-1.1	40 29 21.66	+7 0.02	+1.27	-25	+12	6	22.88	
			10.1067 ⁱⁱ	29.1340 ^{iv}	+12	+.9	-.1	40 28 20.21	+8 1.08	+1.25	+13	+13	5	22.85	57.2
			27.2463 ^{iv}	12.5837 ⁱⁱ	+4	-1.4	.0	40 30 10.77	+6 10.71	+1.29	-22	-10	6	22.71	
			12.1304	28.4037	+38	-.9	+.1	40 43 15.51	-6 51.52	+16	-11	-12	7	23.99	
			23.1643	19.5677	+42	-.4	+.2	40 37 53.98	-1 31.04	+3	-4	-3	11	23.01	
			24.8663	15.4423	+13	+2.1	-.1	40 40 21.12	-3 58.29	+9	+33	-7	6	23.24	57.8
Sep. 12	III 1	D	33.6713 ^{iv}	6.2220 ⁱⁱ	-2	-.7	.0	40 24 47.93	+11 33.98	+1.16	-11	+20	6	23.22	
			14.6940	26.9157	+85	+1.9	+1.9	40 41 31.35	-5 9.21	+12	+54	-10	7	22.77	58.4
			13.2550	29.9187	+229	+.3	+.2	40 43 24.59	-7 1.88	+17	+7	-15	9	22.89	62.5
			32.4533 ^{iv}	7.2647 ⁱⁱ	-6	+.3	+.9	40 47 1.28	-10 36.81	-1.19	+16	-25	11	23.30	
			32.0240 ^{iv}	7.8063 ⁱⁱ	-4	-2.0	-2.2	40 26 9.90	+10 12.27	+1.20	-60	+17	5	22.99	62.1
			31.2757 ^{iv}	7.2857 ⁱⁱ	-27	-.3	-.6	40 26 15.27	+10 6.45	+1.20	-12	+18	6	23.04	
			21.4783	16.8743	-34	+.9	+.3	40 38 18.94	-1 56.31	+4	+24	-3	6	22.94	61.3
			18.4243	20.9777	-8	-1.1	-.5	40 37 27.34	-1 4.54	+2	-24	-2	6	22.62	
			22.7877	17.1267	-2	+1.1	-.1	40 33 59.81	+2 23.12	-6	+16	+3	6	23.12	
			25.9970	11.2190	-110	+1.2	-.1	40 42 36.11	-6 13.17	+15	+18	-10	5	23.22	61.4
	IV 1	D	20.3370	18.4220	-12	+1.3	+.1	40 37 10.89	-48.39	+2	+22	-4	13	22.83	60.8
			18.9130	20.2737	-4	-2.4	-1.9	40 36 57.36	-34.39	+1	-63	-1	11	22.45	
			12.0733	28.2203	+20	+.3	-1.8	40 29 34.74	+6 48.28	-16	-17	+13	7	22.89	60.6
			21.5480	16.0823	+59	+.5	-.2	40 38 40.44	-2 18.04	+5	+5	-3	10	22.57	
			11.1020 ⁱⁱ	27.6857 ^{iv}	+27	+.4	-.1	40 29 21.90	+6 59.34	+1.27	+5	+12	6	22.74	60.5
			29.5483 ^{iv}	10.5127 ⁱⁱ	0	-.4	-.1	40 28 20.46	+8 1.26	+1.25	-8	+13	5	23.07	60.4
			12.3910 ⁱⁱ	27.0537 ^{iv}	+12	-1.6	-2.2	40 30 11.02	+6 10.74	+1.29	-53	+10	6	22.68	
			26.4833	10.1647	-238	-.5	-1.5	40 43 15.75	-6 51.97	+16	-27	-12	7	23.62	
			17.8927	21.5347	-10	+1.8	+1.9	40 37 54.20	-1 32.05	+3	+53	-3	11	22.79	
			14.8863	24.3323	-31	+.8	+.2	40 40 21.39	-3 58.74	+9	+15	-7	6	22.88	59.6
Sep. 15	III 2	R	5.9343 ⁱⁱ	33.3563 ^{iv}	-24	+1.6	+1.2	40 24 48.19	+11 33.23	+1.16	+41	+20	6	23.25	
			25.3267	13.0857	-85	+1.9	+1.8	40 41 31.59	-5 9.27	+12	+53	-10	7	22.94	60.0
			10.0993 ⁱⁱ	35.2947 ^{iv}	+123	+1.3	+.5	40 47 1.32	-10 37.31	-1.19	+27	-25	11	22.95	76.0
			8.1270 ⁱⁱ	32.3433 ^{iv}	+8	-2.4	-.8	40 26 10.00	+10 12.26	+1.20	-74	+17	5	22.94	
			8.6090 ⁱⁱ	32.5770 ^{iv}	+21	+1.3	+2.0	40 26 15.39	+10 6.02	+1.20	+46	+18	6	23.31	
			26.3870	15.7417	+99	+1.6	+1.6	40 31 53.04	+4 29.39	-11	+46	+9	7	22.94	75.6
			18.5173	23.1330	+33	+.2	+.1	40 38 19.16	-1 56.78	+4	+4	-3	6	22.49	
			21.9403	19.3517	+14	+1.4	+.5	40 37 27.60	-1 5.49	+2	+29	-2	6	22.46	75.2
			18.3907	24.0507	+60	-1.7	-1.8	40 34 0.10	+2 23.25	-6	-50	+3	6	22.88	
			12.3580	27.1643	-39	+.3	+.8	40 42 36.44	-6 14.24	+15	+15	-10	5	22.45	74.9

1894	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
Sep. 15	IV 1	R	19.2837	21.2160	+ 2	+1.4	+1.7	40 37 11.39	- 48.86	+ 2	+ 44	- 4	13	40 36 23.08	72.4
			21.1520	19.7447	+ 4	+1.6	+2.2	40 36 57.90	- 35.59	+ 1	+ 53	- 1	11	22.95	
			26.5633	10.4297	-211	+ .7	+1.4	40 29 35.36	+ 6 47.36	- 16	+ 29	+13	7	23.05	71.8
			17.3127	22.7840	+ 3	- .4	+ .1	40 38 41.03	- 2 18.33	+ 5	- 5	- 3	10	22.77	
			27.9283 ^{iv}	11.8793 ⁱⁱ	+ 11	+ .9	+ .8	40 29 22.58	+ 6 58.42	+1.27	+ 24	+12	6	22.69	
	6		9.4767 ⁱⁱ	28.4887 ^{iv}	+ 8	+ .2	- .4	40 28 21.16	+ 8 0.69	+1.25	- 2	+13	5	23.26	70.9
			27.0147 ^{iv}	12.4215 ⁱⁱ	+ 13	+ .2	+2.0	40 30 11.73	+ 6 8.99	+1.29	+ 28	+10	6	22.45	
			12.2427	28.5840	+ 59	+ .9	+1.1	40 43 16.45	- 6 53.29	+ 16	+ 29	-12	7	23.56	
			22.3160	18.7053	+ 15	- .4	-1.7	40 37 54.82	- 1 31.34	+ 3	- 28	- 3	11	23.31	69.9
			25.1927	15.7203	- 4	+1.7	+ .8	40 40 22.12	- 3 59.58	+ 9	+ 37	- 7	6	22.99	
Oct. 2	IV 1	D	33.3290 ^{iv}	5.9210 ⁱⁱ	- 26	- .5	+ .3	40 24 48.91	+11 32.87	+1.16	- 4	+20	6	23.16	
			14.0213	26.2703	+ 15	+ .3	+1.2	40 41 32.32	- 5 9.72	+ 12	+ 20	-10	7	22.89	70.9
			21.0260	18.9793	0	+1.9	+1.2	40 37 14.45	- 51.75	+ 1	+ 45	- 2	13	23.27	62.5
			19.5810	21.1090	+ 2	- .3	0	40 37 1.22	- 38.74	+ 1	- 5	- 1	11	22.54	
			11.5617	27.5290	- 63	+2.2	+ .3	40 29 39.09	+ 6 43.53	- 9	+ 39	+13	7	23.12	
	4		22.1723	16.5310	- 34	-1.0	- .2	40 38 44.64	- 2 22.54	+ 3	- 18	- 5	10	22.00	
			11.0813 ⁱⁱ	27.4760 ^{iv}	+ 24	+1.1	+ .1	40 29 26.67	+ 6 54.56	+1.35	+ 20	+12	6	22.96	61.2
			30.3110 ^{iv}	11.4707 ⁱⁱ	- 8	-1.2	- .9	40 28 25.41	+ 7 56.31	+1.33	- 31	+13	5	22.92	
			28.0077	11.4903	- 38	+1.2	- .4	40 43 20.71	- 6 57.50	+ 10	+ 14	-12	7	23.40	60.4
			16.8470	20.6203	- 43	+ .6	- .1	40 37 58.69	- 1 35.29	+ 2	+ 8	- 3	11	23.58	
Oct. 5	IV 1	R	13.9120	23.5433	-107	-1.4	- .1	40 40 26.63	- 4 3.24	+ 6	- 24	- 7	6	23.20	59.5
			6.5083 ⁱⁱ	33.7637 ^{iv}	+ 7	-1.2	-2.2	40 24 53.34	+11 29.10	+1.29	- 47	+20	6	23.52	
			26.0323	13.6360	- 19	+1.1	+1.3	40 41 36.71	- 5 13.86	+ 7	+ 34	-10	7	23.23	59.2
			19.7177	21.7777	+ 13	+ .2	-1.1	40 37 15.00	- 52.11	+ 1	- 11	- 2	13	22.90	55.9
			21.7903	20.2680	+ 13	-1.3	-1.3	40 37 1.79	- 38.52	+ 1	- 37	- 1	11	23.01	
	3		29.1410	13.2200	+163	0	+1.6	40 29 39.74	+ 6 42.93	- 9	+ 20	+13	7	22.98	55.8
			18.6387	24.2823	+ 73	- .8	- .2	40 38 45.29	- 2 22.87	+ 3	- 15	- 5	10	22.35	55.6
			27.0713 ^{iv}	10.7130 ⁱⁱ	+ 34	+ .7	+ .4	40 29 27.39	+ 6 53.66	+1.35	+ 16	+12	6	22.74	
			10.1770 ⁱⁱ	28.9337 ^{iv}	4	+ .8	- .4	40 28 26.16	+ 7 55.49	+1.33	+ 8	+13	5	23.24	55.2
			26.8337 ^{iv}	12.4183 ⁱⁱ	+ 19	- .2	- .1	40 30 16.77	+ 6 4.50	+1.36	- 4	+10	6	22.75	
Oct. 6	IV 1	D	12.0500	28.5807	+ 46	-1.5	- .6	40 43 21.45	- 6 53.05	+ 10	- 31	-12	7	23.14	55.0
			22.3637	18.5620	+ 17	- .9	- .2	40 37 59.39	- 1 36.16	+ 2	- 17	- 3	11	23.16	
			24.2937	14.6303	- 46	+ .8	+1.5	40 40 27.43	- 4 4.20	+ 6	+ 33	- 7	6	23.60	54.4
			33.1350 ^{iv}	5.9400 ⁱⁱ	- 30	0	+ .6	40 24 54.14	+11 27.48	+1.29	+ 8	+20	6	23.25	
			14.2133	26.6460	+ 47	-1.1	0	40 41 37.51	- 5 14.45	+ 7	+ 18	-10	7	23.28	54.9
	IV 1	D	19.2977	17.1927	- 32	+2.9	+2.4	40 37 15.15	- 53.14	+ 1	+ 77	- 2	13	22.90	
			17.7310	19.2710	- 20	-1.5	-1.1	40 37 1.96	- 38.88	+ 1	- 38	- 1	11	22.81	
			12.5567	28.5027	+ 72	+1.7	+ .6	40 29 39.94	+ 6 43.33	- 9	+ 35	+13	7	23.73	53.3
			21.8577	16.2153	- 48	- .3	- .7	40 38 45.49	- 2 22.53	+ 3	- 14	- 5	10	22.90	53.3
			12.5103 ⁱⁱ	28.8947 ^{iv}	- 23	+1.3	- .9	40 29 27.61	+ 6 54.18	+1.35	+ 9	+12	6	23.41	
I	1	D	29.3140 ^{iv}	10.5163 ⁱⁱ	0	+ .1	+ .2	40 28 26.39	+ 7 55.25	+1.33	+ 4	+13	5	23.19	
			12.8693 ⁱⁱ	27.2837 ^{iv}	- 5	+1.1	- .2	40 30 17.01	+ 6 4.42	+1.36	+ 15	+10	6	23.10	52.1
			27.0770	10.4933	-176	+2.0	+1.1	40 43 21.70	- 6 58.83	+ 10	+ 46	-12	7	23.38	
			17.9880	21.8317	- 3	+ .6	+ .6	40 37 59.62	- 1 37.17	+ 2	+ 17	- 3	11	22.72	51.1
			15.2120	24.9013	+ 4	0	+ .4	40 40 27.69	- 4 4.98	+ 6	+ 5	- 7	6	22.81	
	12		6.5387 ⁱⁱ	33.7447 ^{iv}	+ 8	- .6	+ .5	40 24 54.40	+11 27.85	+1.29	- 3	+20	6	23.77	
			25.5140	13.0583	- 77	- .7	-2.2	40 41 37.77	- 5 14.71	+ 7	- 39	-10	7	22.71	51.0
			27.2237	12.2463	- 38	-2.0	-1.9	40 42 42.19	- 6 18.57	+ 9	- 56	-13	8	23.10	46.7
			22.3747	17.8957	+ 7	- .9	- .4	40 34 30.26	+ 1 53.26	- 3	- 19	+ 4	9	23.43	
			27.3663	13.4797	+ 56	- .2	- .2	40 42 14.47	- 5 51.23	+ 8	- 5	-10	6	23.23	
I	4		18.6440	21.8163	+ 5	- .3	+1.8	40 37 43.15	- 1 20.22	+ 2	+ 17	- 3	7	23.16	47.0
			16.5987	25.2990	+ 71	0	+ .1	40 32 43.47	+ 3 40.14	- 5	+ 1	+ 7	7	23.71	46.7
			23.8817	16.7483	+ 26	-1.6	-1.8	40 33 23.22	+ 3 0.41	- 4	- 48	+ 5	6	23.22	
			27.4460	11.6737	- 60	+ .3	+1.0	40 43 2.23	- 6 38.61	+ 9	+ 17	-12	7	23.83	
			22.8757	16.0973	- 30	- .3	0	40 33 32.02	+ 2 51.30	- 4	- 5	+ 5	6	23.34	46.6

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
Oct. 11	IV	R	18.7487	20.8370	— 5	+2.4	+1.1	40 37 15.63	— 52.78	+ 1	+ 53	— 2	13	40 36 23.55	51.4
			21.2057	19.6507	+ 4	— .8	— 1.4	40 37 2.56	— 39.32	+ 1	— 30	— 1	11	23.05	
			27.2717	11.3383	— 93	— .4	— 1.4	40 29 40.66	+ 6 42.60	— 9	— 24	+12	7	23.12	51.3
			17.6803	23.3550	+ 29	— .7	+1.2	40 38 46.21	— 2 23.54	+ 3	+ 5	— 5	10	22.80	
			27.7093 ^{iv}	11.3823 ⁱⁱ	+ 15	+ .8	+ .1	40 29 28.46	+ 6 52.82	+1.35	+ 14	+12	6	22.95	50.0
	I	R	12.9483	27.9597	+ 60	+3.1	+1.4	40 42 42.55	— 6 19.67	+ 9	+ 68	—13	8	23.60	43.5
			17.8587	22.2973	+ 4	+ .8	+ .5	40 34 30.55	+ 1 52.23	— 3	+ 19	+ 2	9	23.05	
			11.7957	25.7570	—149	— .7	+ .9	40 42 14.94	— 5 52.60	+ 8	— 0	—10	6	22.38	
			23.0567	19.8817	+ 42	+ .8	+ .7	40 37 43.35	— 1 20.38	+ 2	+ 22	— 3	7	23.25	44.6
			24.6593	15.9717	+ 27	—1.1	+ .7	40 32 43.61	+ 3 39.71	— 5	— 9	+ 7	7	23.32	42.8
			17.0263	24.1790	+ 39	—1.5	—2.3	40 33 23.30	+ 3 0.93	— 4	— 53	+ 5	6	23.77	
			11.7543	27.5480	— 50	+ .4	+ .8	40 43 2.26	— 6 39.17	+ 9	+ 16	—12	7	23.29	44.4
			17.0427	23.8280	+ 25	+ .2	— .8	40 33 31.94	+ 2 51.61	— 4	— 7	+ 5	6	23.55	43.4
			16.8423	21.8067	— 29	+ .7	+1.2	40 38 28.22	— 2 5.44	+ 3	+ 26	— 4	7	23.10	
			31.0603 ^{iv}	9.2710 ⁱⁱ	+ 2	+ .6	+1.6	40 27 10.46	+ 9 10.87	+1.32	+ 32	+20	9	23.26	44.2
Oct. 15	IV	D	20.9443	18.8573	0	— .4	—1.3	40 37 16.10	— 52.76	+ 1	— 23	— 2	13	23.23	46.6
			18.6217	20.1937	— 8	—2.3	—2.0	40 37 3.03	— 39.72	+ 1	— 62	— 1	11	22.80	
			11.8283	27.7453	— 30	+ .4	+ .1	40 29 41.21	+ 6 42.34	— 9	+ 7	+12	7	23.72	46.2
			22.1020	16.3783	— 39	— .0	— .0	40 38 46.76	— 2 24.61	+ 3	— 0	— 5	10	22.23	
			11.6343 ⁱⁱ	27.9550 ^{iv}	+ 7	0	— .2	40 29 29.09	+ 6 52.64	+1.35	— 2	+12	6	23.24	
			29.2757 ^{iv}	10.5260 ⁱⁱ	+ 1	—1.2	— .6	40 28 27.97	+ 7 54.04	+1.33	— 27	+13	5	23.25	45.8
			13.4077 ⁱⁱ	27.7573 ^{iv}	— 31	+1.0	+ .5	40 30 18.64	+ 6 2.71	+1.36	+ 22	+10	6	23.09	45.6
			16.8700	20.7623	— 40	— .1	— .4	40 38 1.15	+ 1 38.31	+ 2	— 6	— 3	11	22.88	45.4
			15.0147	24.7497	— 10	—2.1	— .4	40 40 29.52	— 4 6.10	+ 6	— 39	— 7	6	23.08	45.2
			6.8567 ⁱⁱ	33.9840 ^{iv}	+ 26	— .2	—1.0	40 24 56.22	+11 25.91	+1.29	— 15	+20	6	23.53	
Oct. 16	IV	R	25.3320	12.7780	—105	+ .4	— .0	40 41 39.61	— 5 17.13	+ 7	+ 5	—10	7	22.57	45.1
			18.3093	20.4517	— 11	+3.8	+3.3	40 37 16.24	— 54.14	+ 1	+1.03	— 2	13	23.25	53.3
			19.6683	18.0703	— 15	+ .2	— .4	40 37 3.18	— 40.36	+ 1	— 2	— 1	11	22.91	
			28.2763	12.4290	+ 49	+1.8	+ .8	40 29 41.37	+ 6 40.78	— 9	+ 39	+12	7	22.64	53.1
			17.1200	22.8723	0	+1.3	+1.4	40 38 46.92	— 2 25.43	+ 3	+ 39	— 5	10	21.96	
			26.1423 ^{iv}	9.8870 ⁱⁱ	+ 63	+1.5	+2.4	40 29 29.28	+ 6 51.13	+1.35	+ 54	+12	6	22.48	
			10.4490 ⁱⁱ	29.1777 ^{iv}	— 1	+1.4	— .0	40 28 28.17	+ 7 53.50	+1.33	+ 22	+13	5	23.40	51.9
			27.5913 ^{iv}	13.2743 ⁱⁱ	— 22	+1.2	+2.1	40 30 18.84	+ 6 1.91	+1.36	+ 46	+10	6	22.73	
			12.1680	28.8187	+ 72	+2.0	+2.6	40 43 23.55	— 7 1.15	+ 10	+ 65	—12	7	23.10	
			23.6167	19.7310	+ 57	+2.3	+1.4	40 38 1.34	— 1 38.38	+ 2	+ 54	— 3	11	23.60	54.5
Oct. 17	IV	D	24.2357	14.4447	— 56	+2.0	+ .8	40 40 29.74	— 4 7.40	+ 6	+ 42	— 7	6	22.81	54.1
			33.1823 ^{iv}	6.0707 ⁱⁱ	— 23	— .4	— .6	40 24 56.44	+11 25.39	+1.29	— 14	+20	6	23.24	
			13.6500	26.1623	— 9	—1.6	— .8	40 41 39.83	— 5 16.32	+ 7	— 36	—10	7	23.19	54.4
			21.8697	17.4440	— 23	— .0	— .1	40 34 30.58	+ 1 51.83	— 3	— 1	+ 4	9	22.50	51.1
			26.6533	12.7370	— 36	+1.4	+ .8	40 42 14.95	— 5 51.74	+ 8	+ 32	—10	6	23.57	
	I	R	17.6877	20.8747	— 19	+1.5	+ .5	40 37 43.29	— 1 20.53	+ 2	+ 30	— 3	7	23.12	50.6
			15.3330	24.0327	— 26	+ .5	— .0	40 32 43.49	+ 3 39.88	— 5	+ 8	+ 7	7	23.54	
			24.2603	17.1313	+ 45	— .7	— .4	40 33 23.12	+ 3 0.35	— 4	— 16	+ 5	6	23.38	
			27.3163	11.5537	— 80	— .2	+ .1	40 43 2.04	— 6 38.31	+ 9	— 1	—12	7	23.76	50.7
			23.7380	16.9630	+ 23	—1.4	— .2	40 33 31.57	+ 2 51.35	— 4	— 25	+ 5	6	22.74	50.1
	IV	D	21.9943	17.0833	— 20	—2.1	—1.9	40 38 27.84	— 2 4.11	+ 3	— 58	— 4	7	23.21	
			7.3300 ⁱⁱ	29.1480 ^{iv}	— 28	+ .4	— .1	40 27 10.04	+ 9 11.54	+1.32	+ 5	+20	9	23.24	50.4
			19.2540	17.1227	— 34	+1.4	— .2	40 37 16.38	— 53.80	+ 1	— 20	— 2	13	22.90	55.4
			18.2107	19.8133	— 13	— .5	+ .7	40 37 3.33	— 40.48	+ 1	+ 1	— 1	11	22.97	55.3
			10.6277	26.5067	—199	+1.5	+ .2	40 29 41.55	+ 6 40.95	— 9	+ 26	+12	7	22.86	53.6
Oct. 18	IV	D	22.1593	16.4277	— 38	— .4	+ .5	40 38 47.10	— 2 24.81	+ 3	— 0	— 5	10	22.37	
			10.5430 ⁱⁱ	26.8603 ^{iv}	+ 42	+ .2	+ .2	40 29 29.47	+ 6 52.65	+1.35	+ 5	+12	6	23.70	
			29.7867 ^{iv}	11.1103 ⁱⁱ	— 1	+2.4	+3.8	40 28 28.38	+ 7 52.18	+1.33	+ 87	+13	5	22.94	53.6
			13.3403 ⁱⁱ	27.6616 ^{iv}	— 25	+ .7	— .0	40 30 19.05	+ 6 2.00	+1.36	+ 11	+10	6	22.68	
			26.9083	10.2633	—207	+1.6	—1.1	40 43 23.77	— 7 0.30	+ 10	+ 12	—12	7	23.64	

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther. nom.
						A	B		Micrometer.	δ	l	r	Mer		
Oct. 17	IV 9 D		17.2040	21.0947	-31	+ .7	- .3	40 38 1.54	- 1 38.29	+ 2	+ 7	- 3	11	40 36 23.42	53.4
			14.4263	24.1910	-59	+2.3	+1.4	40 40 29.97	- 4 6.72	+ 6	- 54	- 7	6	22.76	
			6.3003 ⁱⁱ	33.4243 ^{iv}	- 9	- .8	- .8	40 24 56.67	+11 25.73	+1.29	- 23	+20	6	23.72	52.9
			11.9907	26.9923	-66	+1.1	-1.3	40 42 42.66	- 6 19.11	+ 9	+ 1	-13	8	23.60	48.2
			18.5347	23.0023	+ 29	-2.5	-2.3	40 34 30.59	+ 1 53.03	- 3	- 70	+ 4	9	23.02	
	I 1 R														
			13.5210	27.4170	+ 57	- .9	-1.1	40 42 14.95	- 5 51.47	+ 8	- 28	-10	6	23.24	
			24.4190	21.2703	+ 80	+ .4	- .4	40 37 43.28	- 1 19.81	+ 2	+ 1	- 3	7	23.54	48.8
			25.1053	16.3907	+ 56	-2.3	-1.6	40 32 43.47	+ 3 40.47	- 5	- 57	+ 7	7	23.46	
			16.9923	24.1380	+ 37	-1.4	-1.8	40 33 23.08	+ 3 0.75	- 4	- 45	+ 5	6	23.45	
Oct. 18	IV 1 R		12.4377	28.1867	+ 42	-1.9	-1.7	40 43 1.99	- 6 38.28	+ 9	- 52	-12	7	23.23	
			17.1107	23.9413	+ 32	-2.1	-2.4	40 33 31.50	+ 2 52.77	- 4	- 64	+ 5	6	23.70	48.0
			18.9133	23.8220	+ 60	-2.1	- .4	40 38 27.75	- 2 4.25	+ 3	- 39	- 4	7	23.17	
			32.1443 ^{iv}	10.5427 ⁱⁱ	+ 18	.0	+ .4	40 27 9.94	+ 9 11.24	+1.32	+ 5	+20	9	22.84	48.3
			19.8810	21.9920	+ 17	.0	- .8	40 37 16.52	- 53.41	+ 1	- 10	- 2	13	23.13	50.8
	I 1 R		21.1630	19.5920	+ 3	-2.1	-2.6	40 37 3.49	- 39.73	+ 1	- 67	- 1	11	23.20	
			26.7913	10.8870	-160	-2.8	- .8	40 29 41.72	+ 6 41.69	- 9	- 55	+12	7	22.96	51.4
			17.5630	23.3100	+ 22	- .3	+1.2	40 38 47.28	- 2 25.23	+ 3	+ 10	- 5	10	22.23	
			27.5030 ^{iv}	11.2120 ⁱⁱ	+ 23	-1.7	-1.1	40 29 29.67	+ 6 51.93	+1.35	- 41	+12	6	22.72	
			10.6953 ⁱⁱ	29.4077 ^{iv}	- 1	+1.3	+1.2	40 28 28.59	+ 7 53.09	+1.33	+ 36	+13	5	23.55	50.2
Oct. 19	IV 1 R		26.8287 ^{iv}	12.5067 ⁱⁱ	+ 18	- .9	-1.0	40 30 19.27	+ 6 2.14	+1.36	- 27	+10	6	22.66	50.5
			10.4610	27.1247	-180	- .4	+ .9	40 43 23.98	- 7 0.84	+ 10	+ 5	-12	7	23.24	
			19.8950	15.9607	- 70	+ .8	+ .3	40 38 1.75	- 1 39.29	+ 2	+ 17	- 3	11	22.73	
			24.3547	14.5537	-46	+1.6	+ .2	40 40 30.22	- 4 7.68	+ 6	+ 28	- 7	6	22.87	49.4
			33.4680 ^{iv}	6.3570 ⁱⁱ	- 6	-1.3	.0	40 24 56.91	+11 25.41	+1.29	- 21	+20	6	23.66	
	I 1 D		13.6657	26.2483	- 5	+1.0	+ .4	40 41 40.30	- 5 18.10	+ 7	+ 21	-10	7	22.45	49.6
			26.6807	11.6723	-109	-1.9	- .9	40 42 42.73	- 6 19.17	+ 9	- 41	-13	8	23.19	42.7
			21.8540	17.4067	- 15	- .2	- .6	40 34 30.61	+ 1 52.40	- 3	- 10	+ 4	9	23.01	
			27.0443	13.1403	+ 11	-1.1	- .8	40 42 14.97	+ 5 51.55	+ 8	- 28	-10	6	23.18	
			17.9960	21.1720	- 12	- .6	- .8	40 37 43.29	- 1 20.27	+ 2	- 19	- 3	7	22.89	44.1
Oct. 19	IV 1 D		15.6197	24.3363	- 4	+ .1	- .3	40 32 43.45	+ 3 40.37	- 5	- 2	+ 7	7	23.89	
			23.8380	16.6900	+ 15	-1.6	- .4	40 33 23.06	+ 3 0.76	- 4	- 31	+ 5	6	23.58	
			27.2640	11.4847	- 90	+ .8	- .3	40 43 1.96	- 6 38.71	+ 9	+ 9	-12	7	23.38	43.6
			23.5877	16.7897	+ 11	- .9	- .5	40 33 31.43	+ 2 51.90	- 4	- 21	+ 5	6	23.19	43.5
			22.9700	18.0207	+ 22	+1.3	+1.4	40 38 27.67	- 2 5.19	+ 3	+ 38	- 4	7	22.92	
	I 1 D		9.3767 ⁱⁱ	31.2183 ^{iv}	+ 2	+ .5	+ .6	40 27 9.86	+ 9 12.21	+1.32	+ 15	+20	9	23.83	43.7
			19.8913	17.7620	- 22	+ .7	+ .6	40 37 16.66	- 53.78	+ 1	+ 19	- 2	13	23.19	54.0
			19.0630	20.6893	- 1	+ .3	+ .9	40 37 3.63	- 41.11	+ 1	+ 16	- 1	11	22.79	
			11.7173	27.6123	-46	-1.0	-1.7	40 29 41.89	+ 6 41.75	- 9	- 37	+12	7	23.37	53.7
			21.8233	16.0950	- 53	-1.1	- .7	40 38 47.45	- 2 24.69	+ 3	- 27	- 5	10	22.57	
Oct. 19	IV 1 D		10.5080 ⁱⁱ	26.7997 ^{iv}	+ 44	- .3	- .7	40 29 29.86	+ 6 52.00	+1.35	- 14	+12	6	23.25	
			29.4677 ^{iv}	10.7460 ⁱⁱ	- 1	-2.6	-2.6	40 28 28.79	+ 7 53.33	+1.33	- 75	+13	5	22.88	
			13.0933 ⁱⁱ	27.4057 ^{iv}	- 12	+2.3	+ .7	40 30 19.48	+ 6 1.82	+1.36	+ 46	+10	6	23.28	53.6
			26.9190	10.2547	-206	+1.7	+1.2	40 43 24.21	- 7 0.79	+ 10	+ 42	-12	7	23.89	
			18.2210	22.1420	+ 6	- .1	+ .7	40 38 1.96	- 1 39.15	+ 2	+ 7	- 3	11	22.98	
	I 1 D		15.2093	24.9830	+ 7	- .6	+ .9	40 40 30.46	- 4 7.12	+ 6	+ 2	- 7	6	23.41	52.7
			6.0197 ⁱⁱ	33.1290 ^{iv}	- 28	-1.2	-1.3	40 24 57.14	+11 25.31	+1.29	- 36	+20	6	23.64	51.8
			24.8200	12.2390	-163	- .3	+1.0	40 41 40.54	- 5 17.66	+ 7	- 8	-10	7	22.84	
			13.6887	28.6860	+155	- .2	-1.8	40 42 42.79	- 6 19.56	+ 9	- 25	-13	8	23.02	47.2
			18.3917	22.8293	+ 23	-2.4	.0	40 34 30.65	+ 1 52.25	- 3	- 39	+ 4	9	22.61	
Oct. 19	I 1 D		12.5917	26.5497	- 52	+1.6	+2.3	40 42 15.01	- 5 52.76	+ 8	+ 55	-10	6	22.84	
			22.4857	19.3277	+ 26	+1.1	- .3	40 37 43.31	- 1 19.91	+ 2	+ 14	- 3	7	23.60	47.2
			24.4410	15.7737	+ 8	- .2	+1.9	40 32 43.46	+ 3 39.15	- 5	+ 21	+ 7	7	22.91	*
			17.0693	24.2067	+ 41	.0	- .2	40 33 23.06	+ 3 0.55	- 4	- 3	+ 5	6	23.65	
			12.4567	28.2480	+ 48	+ .6	+ .7	40 43 1.94	- 6 39.36	+ 9	+ 18	-12	7	22.80	
			17.0087	23.8250	+ 26	+ .5	+ .5	40 33 31.38	+ 2 52.40	- 4	+ 14	+ 5	6	23.99	46.3
	I 1 D														

* Fog.

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.		
						A	B		Micrometer.	δ	l	r	Mer				
Oct.	19	I	9	D	18.4800	23.4253	43	— .1	+ .7	40 38 27.61	— 2 5.14	+ 3	+ 2	— 4	7	22.55	○
Oct.	10				32.2237 ^{iv}	10.3930 ⁱⁱ	19	— .2	+ .1	40 27 9.79	+ 9 11.98	+ 1.32	— 1	+ 20	9	23.37	46.5
20	IV	1	R		18.4223	20.5670	10	+ 3.0	+ 2.8	40 37 16.78	— 54.20	+ 1	+ 84	— 2	13	23.54	56.6
			2		21.4203	19.8217	7	— 1.4	— 1.9	40 37 3.76	— 40.44	+ 1	— 46	— 1	11	22.97	57.2
			3		27.7563	11.9123	24	+ .3	+ 2.2	40 29 42.04	+ 6 40.51	— 9	+ 32	+ 12	7	22.97	
			4		16.0137	21.7887	56	+ 2.2	+ 2.4	40 38 47.61	— 2 25.86	+ 3	+ 65	— 5	10	22.48	56.6
			5		27.5390 ^{iv}	11.2890 ⁱⁱ	22	+ 1.3	+ 2.2	40 29 30.04	+ 6 50.89	+ 1.35	+ 48	+ 12	6	22.94	
			6		10.7277 ⁱⁱ	29.4270 ^{iv}	1	+ .9	— .1	40 28 28.99	+ 7 52.76	+ 1.33	+ 11	+ 13	5	23.37	56.1
			7		26.7537 ^{iv}	12.4283 ⁱⁱ	22	— 1.8	— 1.6	40 30 19.68	+ 6 2.23	+ 1.36	— 49	+ 10	6	22.94	
			8		11.3417	28.0290	47	— .1	+ .2	40 43 24.41	+ 7 1.77	+ 10	+ 1	— 12	7	22.70	
			9		19.7777	15.8630	75	— .2	— 1.9	40 38 2.16	— 1 33.78	+ 2	— 27	— 3	11	23.21	
			10		23.8960	14.0927	85	+ .4	— .2	40 40 30.68	— 4 7.63	+ 6	+ 4	— 7	6	23.14	55.3
			11		33.5497 ^{iv}	6.4677 ⁱⁱ	0	— 1.5	— 1.2	40 24 57.38	+ 11 24.70	+ 1.29	— 39	+ 20	6	23.24	
Oct.	12				12.7207	25.2953	110	— 1.6	— 1.3	40 41 40.78	— 5 17.64	+ 7	— 42	— 10	7	22.76	55.6
27	IV	1	D		20.8133	18.6587	6	+ 1.8	+ .9	40 37 17.20	— 54.51	+ 1	+ 40	— 2	13	23.21	52.8
			2		18.4993	20.1363	10	— 1.4	.0	40 37 4.27	— 41.36	+ 1	— 22	— 1	11	22.80	
			3		12.0243	27.8617	8	+ 1.1	+ 1.4	40 29 42.68	+ 6 40.39	+ 9	+ 35	+ 12	7	23.52	52.8
			4		21.0107	15.2290	96	+ .4	— .2	40 38 48.29	— 2 25.93	+ 3	+ 4	— 5	10	22.48	
			5		11.9883 ⁱⁱ	28.2360 ^{iv}	3	.0	.0	40 29 30.85	+ 6 50.77	+ 1.35	.0	+ 12	6	23.15	
			6		29.5917 ^{iv}	10.9040 ⁱⁱ	2	— 3.6	— 2.7	40 28 29.90	+ 7 52.46	+ 1.33	— 92	+ 13	6	22.96	51.8
			8		28.2873	11.6147	8	— 1.5	+ .6	40 43 25.41	— 7 1.50	+ 10	— 16	— 12	7	23.80	
			9		17.4873	21.4603	19	+ .7	+ .7	40 38 3.13	— 1 40.40	+ 2	+ 20	— 3	11	23.03	
			10		14.9583	24.7967	8	— 1.1	— .6	40 40 31.86	— 4 8.72	+ 6	— 25	— 7	6	22.94	51.0
			11		6.0717 ⁱⁱ	33.1213 ^{iv}	25	+ .2	— .4	40 24 58.57	+ 11 23.81	+ 1.29	— 2	+ 20	6	23.91	
			12		26.7823	14.1640	51	+ 1.0	.0	40 41 42.00	— 5 19.15	+ 7	+ 16	— 10	7	23.05	51.1
		I	1	D	26.7590	11.7193	101	— 1.7	— 1.7	40 42 43.38	— 6 19.98	+ 9	— 49	— 13	8	22.95	46.5
			2		21.7590	17.3460	18	— .9	— .1	40 34 31.13	+ 1 51.53	— 3	— 16	+ 4	9	22.60	
			3		26.8663	12.9467	10	+ .8	— .8	40 42 15.47	— 5 51.89	+ 8	+ 3	— 10	6	23.65	
			4		17.8587	21.0327	16	— 1.6	— 1.5	40 37 43.66	— 1 20.21	+ 2	— 45	— 3	7	23.06	47.4
			5		14.8180	23.5267	63	— .6	— 1.7	40 32 43.71	+ 3 40.02	— 5	— 31	+ 7	7	23.51	47.4
			6		23.6177	16.5017	3	+ .6	+ 1.7	40 33 23.22	+ 2 59.92	— 4	+ 31	+ 5	6	23.52	
			7		27.1893	11.4120	99	+ .1	.0	40 43 2.02	— 6 35.64	+ 9	+ 1	— 12	7	23.43	47.3
			8		24.0040	17.1900	25	— 1.6	— .6	40 33 31.26	+ 2 52.36	— 4	— 33	+ 5	6	23.36	
			9		22.5163	17.5960	2	— .6	— 1.0	40 38 27.41	— 2 4.40	+ 3	— 22	— 4	7	22.85	
			10		8.9483 ⁱⁱ	30.7880 ^{iv}	1	+ .8	.0	40 27 9.51	+ 9 12.28	+ 1.32	+ 13	+ 20	9	23.53	47.5
Oct.	31	I	1	R	12.1630	27.1953	44	+ .4	— 1.9	40 42 43.50	— 6 19.94	+ 9	— 17	— 13	8	23.43	44.4
			2		18.1217	22.5790	14	— 3.4	— 2.7	40 34 31.16	+ 1 52.73	— 3	— 89	+ 4	9	23.10	
			3		13.4477	27.3847	51	— .3	— .2	40 42 15.53	— 5 52.49	+ 8	— 7	— 10	6	23.01	43.8
			4		23.2383	20.0747	46	— .3	.0	40 37 43.66	— 1 20.10	+ 2	— 5	— 3	7	23.57	
		I	5		24.3633	15.6510	2	— 2.1	— 1.1	40 32 43.66	+ 3 40.27	— 5	— 48	+ 7	7	23.54	
			6		17.0517	24.1627	39	.0	.0	40 33 23.13	+ 2 59.88	— 4	— 0	+ 5	6	23.08	
			7		12.6243	28.3680	69	— 1.1	+ .2	40 43 1.88	— 6 38.21	+ 9	— 15	— 12	7	23.56	44.4
			8		16.5780	23.4040	0	— .3	+ .5	40 33 31.02	+ 2 52.58	— 4	+ 1	+ 5	6	23.68	44.0
			9		18.3483	23.3003	35	+ 1.1	+ 2.9	40 38 27.14	— 2 5.29	+ 3	+ 54	— 4	7	22.45	
			10		30.9620 ^{iv}	9.1067 ⁱⁱ	0	— 1.9	— .6	40 27 9.20	+ 9 12.55	+ 1.32	— 38	+ 20	9	22.98	44.3
Nov	1	IV	1	R	19.0290	21.2077	1	+ .5	+ 1.4	40 37 17.61	— 55.08	+ 1	+ 26	— 2	13	22.91	54.7
			2		20.3317	18.7350	6	— 2.3	— 2.6	40 37 4.73	— 41.62	+ 1	— 70	— 1	11	22.52	
			3		29.2307	13.4530	184	+ .8	+ 2.2	40 29 43.22	+ 6 39.36	— 9	+ 40	+ 12	7	23.08	53.8
			4		17.1203	22.9390	0	+ 2.8	+ 2.2	40 38 48.86	— 2 27.11	+ 3	+ 77	— 5	10	22.60	
			5		28.2977 ^{iv}	12.1013 ⁱⁱ	6	+ 1.2	+ 1.4	40 29 31.49	+ 6 49.47	+ 1.35	+ 37	+ 12	6	22.86	
			6		11.0293 ⁱⁱ	29.6723 ^{iv}	3	— .4	— 1.0	40 28 30.60	+ 7 51.33	+ 1.33	— 19	+ 13	5	23.25	52.4
			7		26.8330 ^{iv}	12.5660 ⁱⁱ	16	— 3.3	— 1.2	40 30 21.38	+ 6 0.74	+ 1.36	— 68	+ 10	6	22.96	
			8		12.3820	29.0883	106	— 1.3	+ .2	40 43 26.17	— 72.64	+ 10	— 18	— 12	7	23.40	
			9		22.4807	18.4973	18	— .2	— .8	40 38 3.88	— 1 40.76	+ 2	— 13	— 3	11	23.09	
			10		24.6260	14.7630	25	— .4	— .4	40 40 32.72	— 4 9.30	+ 6	— 11	— 7	6	23.36	50.0

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther- mom.
						A	B		Micrometer.	δ	l	r	Mer		
Nov 1	IV 11	R	33.6240 ^h	6.6430 ^h	7	— .5	.6	40 24 59.44	— 11 22.16	— 1.29	0	— 20	6	23.15	49.6
	12		13.7977	26.4350	— 14	— 1.6	— 1.8	40 41 42.89	— 5 19.54	— 7	— 48	— 10	7	22.91	
	I 1	R	26.4270	11.3890	— 144	— .5	.1	40 42 43.56	— 6 19.83	— 9	— 9	— 13	8	23.68	43.1
	2		22.5570	18.1473	— 14	— .1	+ .4	40 34 31.23	— 1 51.52	— 3	— 3	— 4	9	22.88	
	3		27.8083	13.8803	+ 103	+ 2.3	+ .3	40 42 15.57	— 5 52.39	— 8	— 41	— 10	6	23.63	
	4		18.7597	21.9597	+ 11	+ 2.0	+ 2.0	40 37 43.68	— 1 20.93	— 2	— 58	— 3	7	23.39	44.4
	5		16 1647	24.8447	+ 38	+ 1.8	+ 1.9	40 32 43.63	— 3 39.55	— 5	— 53	— 7	7	23.80	
	6		23.4480	16.3163	— 8	— 1.2	.2	40 33 23.13	— 3 0.29	— 4	— 22	— 5	6	23.27	
	7		27.1667	11.3977	— 101	+ .6	+ .4	40 43 1.87	— 6 38.42	— 9	— 14	— 12	7	23.63	
	8		23.6860	16.8810	+ 18	+ .5	+ 1.5	40 33 30.98	— 2 52.09	— 4	— 27	— 5	6	23.41	43.6
Nov 2	9		22.2313	17.3107	— 11	— .2	— .2	40 38 27.10	— 2 4.38	— 3	— 5	— 4	7	22.73	
	10		9.3563 ^h	31.2167 ^h	+ 3	— .2	— .5	40 27 9.14	— 9 12.69	+ 1.32	— 9	+ 20	9	23.35	43.6
	IV 1	D	20.7663	18.5827	— 6	.0	+ .7	40 37 17.68	— 55.19	— 1	— 9	— 2	13	22.70	56.1
	2		18.9853	20.6827	— 1	+ 1.2	+ 2.2	40 37 4.81	— 42.91	— 1	— 47	— 1	11	22.48	56.7
	3		11.6980	27.5053	— 56	+ .4	.0	40 29 43.31	— 6 39.50	— 9	— 6	+ 12	7	22.97	
	4		22.5277	16.7140	— 21	+ 1.7	+ .1	40 38 48.96	— 2 26.93	— 3	— 29	— 5	10	22.40	
	5		11.0477 ^h	27.2483 ^h	+ 42	+ .2	— .1	40 29 31.60	— 6 49.69	+ 1.35	— 1	+ 12	6	22.33	56.4
	6		29.4847 ^h	10.8627 ^h	— 2	— 1.5	.3	40 28 30.73	— 7 50.80	— 1.33	— 20	— 13	5	22.84	55.9
Nov 3	I 1	R	12.3027 ^h	36.5163 ^h	+ 32	+ 1.9	— .1	40 30 21.51	— 5 59.43	+ 1.36	— 29	+ 10	6	22.75	54.5
			13.7553	28.7800	+ 176	+ .2	— .6	40 42 43.73	— 6 20.30	— 9	— 4	— 13	8	23.43	46.2
	2		17.2840	21.7120	— 20	— .9	— .4	40 34 31.37	— 1 51.90	— 3	— 19	— 4	9	23.18	
	3		13.3600	27.3223	+ 42	+ 1.0	+ 1.7	40 42 15.71	— 5 53.11	— 8	— 37	— 10	6	23.01	
	4		22.5883	19.4120	+ 28	— .4	+ .1	40 37 43.79	— 1 20.37	— 2	— 5	— 3	7	23.43	46.7
	5		24.5887	15.9013	+ 19	— 1.0	— .1	40 32 43.74	— 3 39.69	— 5	— 17	— 7	7	23.35	
	6		15.7460	23.8783	— 13	— .8	— 1.0	40 33 23.19	— 3 0.29	— 4	— 25	— 5	6	23.30	
	7		12.0590	27.8020	— 10	— 2.1	+ 1.2	40 43 1.90	— 6 37.99	— 9	— 19	— 12	7	23.76	46.5
	8		17.2560	24.0753	+ 40	.0	— .9	40 33 30.95	— 2 52.51	— 4	— 11	— 5	6	23.42	46.2
	9		17.6777	22.5763	+ 7	— 1.0	— 1.1	40 38 27.06	— 2 3.87	— 3	— 30	— 4	7	22.95	
Nov 4	IV 1	R	32.5880 ^h	10.7517 ^h	+ 27	+ .6	+ 1.6	40 27 9.03	— 9 12.14	+ 1.32	— 29	+ 20	9	23.12	46.3
			28.4897	26.6463	+ 29	+ 1.7	— 1.2	40 37 17.77	— 54.60	— 1	— 15	— 2	13	23.44	46.9
	2		21.3930	19.7500	+ 7	— .9	— 1.2	40 37 4.91	— 41.56	— 1	— 29	— 1	11	23.17	
	3		26.7297	10.9213	— 164	— .2	+ .3	40 29 43.45	— 6 39.26	— 9	— 1	+ 12	7	23.82	
	4		16.4310	22.2503	— 35	— .3	— .1	40 38 49.12	— 2 27.04	— 3	— 6	— 5	10	22.10	48.2
	5		28.0560 ^h	11.8433 ^h	+ 1	— .4	— .2	40 29 31.79	— 6 49.90	+ 1.30	— 9	+ 12	6	23.08	
	6		10.9720 ^h	29.5777 ^h	— 2	+ 2.2	+ 1.3	40 28 30.95	— 7 50.39	+ 1.28	— 52	+ 13	5	23.32	47.4
	7		28.1050 ^h	13.8593 ^h	— 53	— 1.0	— .6	40 30 21.75	— 6 0.03	+ 1.31	— 23	+ 10	6	23.02	
	8		12.2130	28.9467	+ 84	— .5	+ 1.0	40 43 26.58	— 7 3.28	— 10	— 4	— 13	7	23.38	
	9		21.4627	17.4790	— 19	+ .3	— 1.2	40 38 4.29	— 1 40.67	— 2	— 10	— 4	11	23.61	
	10		24.7540	14.8657	— 16	+ .9	+ .4	40 40 33.20	— 4 9.96	— 6	— 19	— 7	6	23.48	46.5
	11		33.6510 ^h	6.6647 ^h	+ 10	— 1.4	— .6	40 24 59.94	+ 11.22.30	+ 1.24	— 30	+ 20	6	23.44	47.0
Nov 6	I 12		14.3747	27.0507	— 0	— .4	— 1.2	40 41 43.41	— 5 20.68	— 7	— 21	— 10	7	22.56	
	1	D	27.2397	12.1557	— 45	+ .3	.3	40 42 44.05	— 6 21.24	— 9	— 9	— 13	8	22.94	33.4
	2		21.7817	17.3487	— 17	— 3.0	— 1.3	40 34 31.65	— 1 52.03	— 3	— 65	— 4	9	23.13	
	3		27.7473	13.8110	+ 95	— .6	— 1.7	40 42 15.93	— 5 52.58	— 8	— 31	— 10	6	23.13	33.1
	4		17.6000	20.8080	— 23	— 1.6	— .2	40 37 44.03	— 1 21.05	— 2	— 28	— 3	7	22.76	
	5		15.0730	23.7437	— 44	+ 1.7	+ 1.4	40 32 43.95	— 3 39.10	— 5	— 45	— 7	7	23.59	33.1
Nov 10	I 6		23.6417	16.5170	+ 5	— .8	— .1	40 33 23.37	— 3 0.14	— 4	— 14	— 5	6	23.44	
	1	R	13.0773	28.1760	+ 84	+ 2.9	+ 2.7	40 42 44.32	— 6 21.94	— 9	— 81	— 13	8	23.23	34.3
	2		18.3190	22.7087	+ 19	+ 1.4	+ 1.0	40 34 31.87	— 1 51.03	— 3	— 35	— 4	9	23.35	
	3		13.6187	27.5907	+ 74	+ .8	.0	40 42 16.22	— 5 53.43	— 8	— 13	— 10	6	22.96	
	4		21.5343	18.3627	— 3	— 1.4	— 2.1	40 37 44.18	— 1 20.18	— 2	— 49	— 3	7	23.57	
	5		25.0777	16.4047	— 55	— 3.2	— 1.1	40 32 44.09	— 3 39.41	— 5	— 65	— 7	7	22.94	33.9
	6		15.3047	22.4057	— 71	+ 1.7	+ 2.4	40 33 23.48	— 2 59.35	— 4	— 57	— 5	6	23.47	33.5
	7		27.8480	12.0893	— 4	— .1	— .4	40 43 2.12	— 6 38.41	— 9	— 6	— 12	7	23.69	
	8		23.3020	16.5067	— 7	— .1	.0	40 33 31.03	— 2 51.78	— 4	— 1	— 5	6	22.87	33.4

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther- mom.
						A	B		Micrometer.	δ	l	r	Mer		
Nov 10	I 9	R	22.3240	17.4157	— 6	.0	+ .2	40 38 27.06	— 2 4.08	+ 3	+ 2	— 4	7	40 36 23.06	○
Nov 10			9.2200 ⁱⁱ	31.0860 ^{iv}	+ 1	— .2	— 1.2	40 27 9.00	+ 9 12.83	+ 1.27	— 18	+ 20	9	23.21	33.5
Nov 11	IV 1	D	21.2637	19.1007	+ 7	+ .1	— .1	40 37 17.77	— 54.70	+ 1	0	— 2	13	23.19	35.8
	2		15.9110	17.5543	— 43	— 2.7	— 2.4	40 37 4.98	— 41.44	+ 1	— 73	— 1	11	22.92	
	3		11.6877	27.4987	— 56	+ .5	— .8	40 29 43.60	+ 6 39.60	— 9	— 2	+ 12	7	23.28	35.1
	4		22.7637	16.9783	— 5	— 1.2	— .8	40 38 49.36	— 2 26.26	+ 3	— 29	— 5	10	22.89	
	5		12.5017 ⁱⁱ	28.7147 ^{iv}	— 20	— .7	— 1.3	40 29 32.10	+ 6 49.85	+ 1.23	— 28	+ 12	6	23.08	35.0
	6		29.7333 ^{iv}	11.1130 ⁱⁱ	— 4	— 2.2	— .8	40 28 31.36	+ 7 50.75	+ 1.21	— 45	+ 13	5	23.05	
	7		13.6917 ⁱⁱ	27.9223 ^{iv}	— 42	— 1.1	— 1.4	40 30 22.21	+ 5 59.68	+ 1.24	— 35	+ 10	6	22.94	
	8		29.9003	13.1797	+ 224	— .6	— 1.5	40 43 27.10	+ 7 3.80	+ 10	— 28	— 13	7	23.56	34.7
	9		17.5693	21.5833	— 16	— 1.8	— 1.5	40 38 4.86	— 1 41.44	+ 2	— 48	— 4	11	23.03	
	10		15.4727	25.3803	+ 37	— 1.1	— 1.1	40 40 33.90	— 4 10.58	+ 6	— 3	— 7	6	23.34	34.9
	11		6.9240 ⁱⁱ	33.8763 ^{iv}	+ 24	+ .2	— 1.4	40 25 0.68	+ 11 21.48	+ 1.17	— 14	+ 20	6	23.45	
	12		25.7833	13.0737	— 61	— .7	— 1.3	40 41 44.19	— 5 21.17	+ 7	— 28	— 10	7	22.78	34.3
	I 1	D	27.0730	12.0007	— 61	+ .5	+ .2	40 42 44.35	— 6 20.91	+ 9	+ 10	— 13	8	23.58	30.6
	2		20.9597	16.5427	— 50	— 2.2	— .5	40 34 31.89	+ 1 51.55	— 3	— 42	+ 4	9	23.12	
	3		28.4080	14.4707	+ 176	+ .6	— .3	40 42 16.24	— 5 52.81	+ 8	+ 5	— 10	6	23.52	
	4		18.2120	21.4083	— 6	+ .3	+ .1	40 37 44.22	— 1 20.79	+ 2	+ 6	— 3	7	23.55	
	5		15.2613	23.9523	— 29	+ 1.5	— .1	40 32 44.09	+ 3 39.66	— 5	+ 22	+ 7	7	24.06	30.6
	6		23.6273	16.5150	+ 3	+ .9	+ 1.4	40 33 23.48	+ 2 59.82	— 4	+ 3	+ 5	6	23.40	
	7		27.0883	11.3237	— 109	— .6	— 2.2	40 43 2.11	— 6 38.29	+ 9	— 37	— 12	7	23.49	
	8		16.8030	23.6363	+ 15	— .6	— .8	40 33 30.99	+ 2 52.80	— 4	— 20	+ 5	6	23.66	30.0
	9		18.7017	23.5843	+ 50	— 1.8	— .9	40 38 27.01	— 2 3.57	+ 3	— 40	— 4	7	23.10	30.4
Nov 12	IV 1	R	31.4850 ^{iv}	9.6107 ⁱⁱ	+ 7	— 1.7	— 1.4	40 27 8.95	+ 9 13.05	+ 1.20	— 45	+ 20	9	23.04	30.4
			20.0510	22.2133	+ 21	— .2	— .2	40 37 17.81	— 54.72	+ 1	— 5	— 2	13	23.16	31.3
	2		21.1980	19.5147	+ 3	+ 1.3	+ 1.8	40 37 5.02	— 42.57	+ 1	+ 43	— 1	11	22.99	
	3		27.2703	11.4680	— 88	— 1.3	+ .4	40 29 43.65	+ 6 39.30	— 9	— 16	+ 12	7	22.89	31.6
	4		18.0183	23.8267	+ 47	— 1.1	+ 1.4	40 38 49.42	— 2 26.97	+ 3	0	— 5	10	22.53	31.1
	5		28.5250 ^{iv}	12.3287 ⁱⁱ	— 13	+ 1.1	0	40 29 32.17	+ 6 49.45	+ 1.23	+ 18	+ 12	6	23.21	
	6		10.4337 ⁱⁱ	29.0503 ^{iv}	+ 2	+ 2.1	+ 1.1	40 28 31.44	+ 7 50.67	+ 1.21	+ 48	+ 13	5	23.98	30.3
	7		26.3967 ^{iv}	12.2057 ⁱⁱ	+ 37	+ .5	+ .7	40 30 22.30	+ 5 58.87	+ 1.24	+ 17	+ 10	6	22.74	
	8		12.6530	29.4057	+ 149	+ .2	+ 1.2	40 43 27.19	— 7 3.92	+ 10	+ 18	— 13	7	23.49	
	9		20.8023	16.7767	— 44	+ 2.0	+ .1	40 38 4.96	— 1 41.67	+ 2	+ 34	— 4	11	23.72	
	10		24.8117	14.9127	— 12	0	— .2	40 40 34.02	— 4 10.24	+ 6	— 2	— 7	6	23.81	30.8
	11		33.3970 ^{iv}	6.4717 ⁱⁱ	— 3	— 1.0	— .1	40 25 0.81	+ 11 20.73	+ 1.17	— 17	+ 20	6	22.80	30.7
Nov 15	IV 1	D	14.5000	27.2057	+ 93	+ .3	+ .1	40 41 44.42	— 5 21.46	+ 7	+ 6	— 10	7	23.06	
			20.8310	18.6543	— 6	+ .3	+ .3	40 37 17.93	— 55.02	+ 1	+ 9	— 2	13	23.12	43.7
	2		20.7923	21.4750	+ 6	+ 1.7	+ 1.7	40 37 5.16	— 42.56	+ 1	+ 49	— 1	11	23.20	
	3		11.2847	27.0710	— 114	+ 2.7	+ 1.6	40 29 43.83	+ 6 38.83	— 5	+ 63	+ 12	7	23.43	43.6
	4		22.3940	16.5687	— 26	+ .3	— .1	40 33 49.64	— 2 27.21	+ 2	+ 3	— 5	10	22.53	42.9
	5		11.8947 ⁱⁱ	28.0787 ^{iv}	0	+ .1	— 1.0	40 39 22.41	+ 6 49.17	+ 1.27	— 11	+ 12	6	22.92	
	6		29.5933 ^{iv}	11.0147 ⁱⁱ	— 2	— .5	+ .3	40 28 31.72	+ 7 49.71	+ 1.26	— 4	+ 13	5	22.83	
	7		13.6603 ⁱⁱ	27.8397 ^{iv}	— 40	+ 2.0	+ 1.6	40 30 22.60	+ 5 58.39	+ 1.27	+ 52	+ 10	6	22.94	
	8		28.4897	11.6977	+ 13	+ 1.5	+ .8	40 43 27.53	— 7 4.56	+ 5	+ 34	— 13	7	23.30	
	9		17.2520	21.3123	— 28	+ .5	+ .5	40 38 5.32	— 1 42.58	+ 1	+ 14	— 4	11	22.96	44.0
	10		15.4167	25.3693	+ 35	+ .4	+ 1.1	40 40 34.43	— 4 11.71	+ 3	+ 20	— 7	6	22.94	
	11		6.8280 ⁱⁱ	33.7553 ^{iv}	+ 16	— .6	— .2	40 25 1.22	+ 11 20.82	+ 1.23	+ 7	+ 20	6	23.60	43.6
	12		26.6400	13.8987	+ 28	+ .5	+ .5	40 41 44.76	— 5 22.20	+ 4	+ 14	— 10	7	22.71	
	I 1	R	13.1490	28.2387	+ 93	+ 2.0	+ 1.7	40 42 44.58	— 6 21.74	+ 5	+ 54	— 13	8	23.38	42.9
	2		18.7520	23.1777	+ 37	— .2	— .1	40 34 32.06	+ 1 51.99	— 1	— 3	+ 4	9	24.14	42.8
	3		12.2103	26.1987	— 98	— .3	+ 1.9	40 42 16.41	— 5 53.41	+ 4	+ 19	— 10	6	23.19	
	4		21.7830	18.5880	+ 5	+ .7	— .5	40 37 44.34	— 1 20.79	+ 1	+ 5	— 3	7	23.65	41.8
	5		24.8183	16.1600	+ 35	— .4	+ 1.2	40 32 44.13	+ 3 38.99	— 3	+ 8	+ 7	7	23.31	
	6		16.5420	23.6563	+ 7	+ .3	— .1	40 33 23.51	+ 2 59.88	— 2	+ 3	+ 5	6	23.51	
	8		23.4813	16.6500	+ 5	— .2	+ .2	40 33 30.82	+ 2 52.72	— 2	0	+ 5	6	23.63	40.4

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther. mom.
						A	B		Micrometer.	δ	l	r	Mer		
Nov 15	I 9	R	21.3740	16.4710	-47	.0	+.7	40 38 26.86	-2 3.84	+2	+9	-4	7	40 36 23.16	○
Nov 16	IV 10	R	9.0500 ⁱⁱ	30.9247 ^{iv}	0	+1.1	+1.2	40 27 8.74	+9 13.04	+1.25	+33	+20	9	23.65	40.3
			20.4010	22.5993	+28	+1.8	+1.8	40 37 17.95	-55.65	+1	+51	-2	13	22.93	51.1
			27.8213	12.0550	-10	+2.2	+1.7	40 29 43.87	+6 38.58	-5	+57	+12	7	23.16	50.4
			17.0410	22.8723	-1	+.5	+2.1	40 38 49.70	-2 27.43	+2	+34	-5	10	22.68	
			27.9033	11.7517	+6	+1.2	+.8	40 29 32.48	+6 48.36	+1.27	+29	+12	6	22.58	
			10.4210 ⁱⁱ	29.0293 ^{iv}	+2	+2.0	+.6	40 28 31.80	+7 50.47	+1.26	+40	+13	5	24.11	50.2
			27.1247 ^{iv}	12.9317 ⁱⁱ	0	-1.9	-.2	40 30 22.69	+5 58.83	+1.27	-33	+10	6	22.62	48.6
			12.0507	28.8270	+62	-1.9	-.5	40 43 27.64	-7 4.30	+5	-37	-13	7	22.96	
			21.9483	17.9087	-3	+.1	-.5	40 38 5.43	-1 42.12	+1	-3	-4	11	23.36	
			24.6363	14.6963	-30	+1.0	.0	40 40 34.56	-4 11.23	+3	+16	-7	6	23.51	48.1
			33.9737 ^{iv}	7.0647 ⁱⁱ	+31	+.1	.0	40 25 1.36	+11 20.40	+1.23	+1	+20	6	23.26	47.9
			14.2290	26.9187	+55	-1.3	-1.6	40 41 44.90	-5 20.96	+4	-41	-10	7	23.54	
	I 1	D	27.4607	12.3677	-10	-2.4	-1.9	40 42 44.68	-6 21.56	+5	-63	-13	8	22.49	42.4
			20.2030	15.8040	-77	+.8	+1.3	40 34 32.15	+1 51.02	-1	-3	+4	9	23.26	
			28.7493	14.8223	+217	+.2	-.5	40 42 16.50	-5 52.66	+4	-3	-10	6	23.81	
			17.6100	20.8277	-23	-.6	-.7	40 37 44.41	-1 21.29	+1	-18	-3	7	22.99	41.8
			15.3030	23.9753	-27	+.2	+.5	40 32 44.21	+3 39.19	-3	+9	+7	7	23.60	
			22.9240	15.8050	-41	-1.7	-1.5	40 33 23.56	+2 59.88	-2	-46	+5	6	23.07	
			11.4513	27.1937	-94	-2.0	-1.5	40 43 2.12	-6 37.77	+5	-52	-12	7	23.83	41.4
Nov 19			16.0870	22.9133	-30	+1.1	+1.2	40 33 30.89	+2 52.51	-2	+33	+5	6	23.82	41.4
			30.8757 ^{iv}	8.9823 ⁱⁱ	-0	-1.3	-.4	40 27 8.73	+9 13.52	+1.25	-26	+20	9	23.53	41.1
			21.0467	18.8643	-1	.0	+.2	40 37 17.91	-55.17	+1	+2	-2	13	22.88	33.4
			17.2200	18.9160	-30	+.7	+.5	40 37 5.17	-42.80	+1	+18	-1	11	22.66	
			12.3730	28.1747	+37	-.1	-1.0	40 29 43.88	+6 39.60	-5	-14	+12	7	23.48	32.8
			22.2847	16.4617	-34	+.2	.0	40 38 49.76	-2 27.13	+2	+3	-5	10	22.73	
			12.6187 ⁱⁱ	28.7783 ^{iv}	-24	.0	+.8	40 29 32.56	+6 48.49	+1.27	+10	+12	6	22.60	
			29.7780 ^{iv}	11.2200 ⁱⁱ	-4	+.3	+2.2	40 28 31.94	+7 49.18	+1.26	+32	+13	5	22.88	31.4
			12.2940 ⁱⁱ	26.4623 ^{iv}	+32	+1.6	+1.4	40 30 22.86	+5 58.29	+1.27	+43	+10	6	23.01	
			29.7443	12.9443	+198	+.5	+.4	40 43 27.93	-7 5.24	+5	+13	-13	7	22.81	30.5
			17.2573	21.3530	-27	+3.0	+2.1	40 38 5.68	-1 43.48	+1	+75	-4	11	23.03	
			15.4523	25.4437	+34	.0	-.2	40 40 34.86	-4 12.70	+3	-2	-7	6	22.16	30.4
			6.7777 ⁱⁱ	33.6613 ^{iv}	+13	+.3	.0	40 25 1.68	+11 19.71	+1.23	+5	+20	6	22.93	30.5
			25.5090	12.7457	-97	.0	-.3	40 41 45.26	+5 22.44	+4	-4	-10	7	22.79	30.5
	I 1	R	12.9630	28.0240	+62	-1.0	-4.5	40 42 45.04	-6 20.93	+5	-72	-13	8	23.39	21.6
			18.3697	22.7830	+22	-3.3	-5.0	40 34 32.47	+1 51.63	-1	-1.16	+4	9	23.06	
			12.8100	26.7757	-27	-1.9	-1.5	40 42 16.83	-5 53.02	+4	-49	-10	6	23.32	
			22.5567	19.8610	+27	-.7	-2.0	40 37 44.70	-1 20.86	+1	-36	-3	7	23.53	23.5
			24.5150	15.8553	+14	-1.5	+.1	40 32 44.46	+3 38.97	-3	-22	+7	7	23.32	
			16.3307	23.4477	-9	+.5	-1.3	40 33 23.79	+2 59.92	-2	-8	+5	6	23.72	
			12.5173	28.2753	+54	-1.9	.0	40 43 2.31	-6 38.53	+5	-31	-12	7	23.47	22.9
			17.3997	24.2383	+50	-1.2	-.1	40 33 31.01	+2 53.02	-2	-21	+5	6	23.91	22.7
			18.3443	23.2617	+34	+1.0	+1.8	40 38 26.95	-2 4.41	+2	+38	-4	7	22.97	
Nov 20	IV 10	R	31.1050 ^{iv}	9.2247 ⁱⁱ	+1	-1.8	-.4	40 27 8.58	+9 13.19	+1.25	-34	+20	9	22.97	23.4
			20.5257	22.7080	+30	+3.2	+1.8	40 37 17.85	-55.25	+1	+74	-2	13	23.46	30.3
			21.3423	19.6723	+5	+.7	+.5	40 37 5.12	-42.23	+1	+18	-1	11	23.18	
			27.7907	12.0060	-13	-.9	+.1	40 29 43.85	+6 39.04	-5	-13	+12	7	22.90	30.5
			17.4393	23.2670	+16	-1.4	-.3	40 33 49.75	-2 27.38	+2	-26	-5	10	22.18	30.0
			28.5177 ^{iv}	12.3107 ⁱⁱ	-13	-1.8	-1.0	40 29 32.55	+6 49.72	+1.27	-41	+12	6	23.31	
			11.3927 ⁱⁱ	29.9837 ^{iv}	-8	+.6	.0	40 28 31.95	+7 50.00	+1.26	+9	+13	5	23.48	29.2
			26.8103 ^{iv}	12.6323 ⁱⁱ	+16	-.1	+.4	40 30 22.88	+5 58.49	+1.27	+3	+10	6	22.83	
			12.6360	29.4023	+146	-.8	+.4	40 43 27.87	-7 4.26	+5	-8	-13	7	23.52	
			22.0370	17.9927	+1	-1.0	-1.6	40 38 5.72	-1 42.25	+1	-36	-4	11	23.19	29.2
			24.9803	15.0413	-104	-.2	-.6	40 40 34.91	-4 11.02	+3	-10	-7	6	23.81	
			34.7383 ^{iv}	7.8453 ⁱⁱ	+79	-.3	+.2	40 25 1.75	+11 20.12	+1.23	-2	+20	6	23.34	28.9

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther- mom.
						A	B		Micrometer.	δ	l	r	Mer		
Nov															
20	IV 12	R	14.5637	27.2717	+100	-1.3	-2.2	40 41 45.34	- 5 21.54	+ 4	- 48	-10	7	40 36 23.33	
21	IV 1	D	20.6937	18.5387	- 7	+1.4	+1.0	40 37 17.79	- 54.47	+ 1	+ 35	- 2	13	23.79	39.8
	2		20.4387	22.1210	+ 17	- .1	+ .9	40 37 5.07	- 42.58	+ 1	+ 9	- 1	11	22.69	
	3		11.8557	27.6553	- 34	+1.1	.0	40 29 43.80	+ 6 39.36	- 5	+ 18	+12	7	23.48	39.8
	4		22.3893	16.5407	- 28	+1.9	+1.3	40 38 49.72	- 2 27.80	+ 2	+ 47	- 5	10	22.46	39.1
	5		12.8380 ⁱⁱ	29.0363 ^{iv}	- 32	-1.1	- .3	40 29 32.53	+ 6 49.45	+1.27	- 22	+12	6	23.21	
	6		30.0783 ^{iv}	11.5077 ⁱⁱ	- 8	- .2	+1.8	40 28 31.94	+ 7 49.49	+1.26	+ 19	+13	5	23.06	39.2
	7		12.9507 ⁱⁱ	27.1100 ^{iv}	- 1	+2.8	+2.0	40 30 22.88	+ 5 57.98	+1.27	+ 70	+10	6	22.99	
	8		28.4823	11.7103	+ 13	+ .1	- .4	40 43 27.89	- 7 4.07	+ 5	- 3	-13	7	23.78	38.9
	9		18.0480	22.1163	+ 2	+2.0	+ .7	40 38 5.75	- 1 42.86	+ 1	+ 41	- 4	11	23.38	38.6
	10		14.8923	24.8623	- 10	+ .1	+ .6	40 40 34.96	- 4 12.04	+ 3	+ 9	- 7	6	23.03	
	11		7.7377 ⁱⁱ	34.6267 ^{iv}	+ 71	+ .3	- .4	40 25 1.80	+11 20.00	+1.23	0	+20	6	23.29	38.4
Nov	22	IV 1	26.9027	14.1630	+ 58	-1.2	+ .5	40 41 45.40	- 5 22.24	+ 4	- 26	-10	7	22.91	
	2	R	18.5247	20.6963	- 7	+2.6	+ .8	40 37 17.73	- 54.89	+ 1	+ 52	- 2	13	23.48	41.5 ^a
			21.0620	19.4100	+ 2	-1.1	-1.4	40 37 5.02	- 41.77	+ 1	- 35	- 1	11	23.01	41.6
	4		17.5913	23.4160	+ 26	+ .8	+1.1	40 38 49.69	- 2 27.33	+ 2	+ 27	- 5	10	22.70	
	5		28.0037 ^{iv}	11.8363 ⁱⁱ	+ 2	+ .4	+ .1	40 29 32.53	+ 6 48.75	+1.27	+ 8	+12	6	22.81	41.6
	6		10.7070 ⁱⁱ	29.2763 ^{iv}	0	+1.5	+1.6	40 28 31.93	+ 7 49.47	+1.26	+ 44	+13	5	23.28	41.2
	7		26.8330 ^{iv}	12.6617 ⁱⁱ	+ 15	- .2	+1.0	40 30 22.88	+ 5 58.32	+1.27	+ 9	+10	6	22.72	
	8		12.7247	29.5143	+162	.0	+ .3	40 43 27.90	- 7 4.89	+ 5	+ 4	-13	7	23.04	41.1
	9		23.5563	19.5027	+ 55	- .9	-1.4	40 38 5.78	- 1 42.62	+ 1	- 32	- 4	11	22.92	
	10		25.2903	15.3170	+ 26	+2.1	+1.0	40 40 35.00	- 4 12.21	+ 3	+ 46	- 7	6	23.27	41.1
	11		33.7200 ^{iv}	6.8087 ⁱⁱ	+ 15	- .6	- .5	40 25 1.85	+11 20.42	+1.23	- 16	+20	6	23.60	41.2
Nov	24	I 1	14.3287	27.0830	+ 78	- .2	-1.3	40 41 45.45	- 5 22.66	+ 4	- 19	-10	7	23.61	
		D	26.9583	11.8360	- 80	-1.4	-2.2	40 42 45.45	- 6 22.12	+ 5	- 50	-13	8	22.83	35.5
	2		22.2800	17.9163	+ 4	+1.1	+1.1	40 34 32.83	+ 1 50.33	- 1	+ 32	+ 4	9	23.60	
	3		27.6900	13.7113	+ 86	- .2	+ .1	40 42 17.21	- 5 53.63	+ 4	- 1	-10	6	23.57	
	4		18.3613	21.6080	- 2	-1.1	- .5	40 37 45.02	- 1 22.08	+ 1	- 24	- 3	7	22.75	35.5
	6		23.7293	16.6347	+ 12	-1.3	- .4	40 33 24.05	+ 2 59.40	- 2	- 26	+ 5	6	23.28	
	7		27.8870	12.0913	- 2	- .7	- .4	40 43 2.52	- 6 39.35	+ 5	- 16	-12	7	23.01	35.5 ^d
Nov	26	IV 1	23.1597	16.3450	- 17	+ .5	+1.9	40 33 31.13	+ 2 52.25	- 2	+ 32	+ 5	6	23.79	35.4
		D	20.8280	18.6757	- 5	+ .6	+ .3	40 37 17.59	- 54.40	+ 1	+ 13	- 2	13	23.44	32.0
	2		18.7050	20.3593	- 6	.0	- .2	40 37 4.91	- 41.81	+ 1	- 2	- 1	11	23.19	
	3		13.0083	28.8123	+125	+ .3	- .5	40 29 43.66	+ 6 39.88	- 5	- 1	+12	7	23.67	32.1
	4		23.3680	17.5610	+ 22	- .8	- .4	40 38 49.66	- 2 26.87	+ 2	- 18	- 5	10	22.68	32.0
	5		12.0317 ⁱⁱ	28.2287 ^{iv}	- 3	-1.2	-1.7	40 29 32.47	+ 6 49.49	+1.27	- 41	+12	6	23.00	
	6		30.3323 ^{iv}	11.7713 ⁱⁱ	- 13	+2.0	+1.5	40 28 31.95	+ 7 49.23	+1.26	+ 51	+13	5	23.13	31.9
	7		13.6867 ⁱⁱ	27.8743 ^{iv}	- 42	+ .9	+ .2	40 30 22.93	+ 5 58.59	+1.27	+ 12	+10	6	23.07	
	8		28.3207	11.5277	- 13	+ .4	- .8	40 43 28.00	- 7 4.53	+ 5	- 4	-13	7	23.42	
	9		18.9810	23.0493	+ 36	+ .2	.0	40 38 5.94	- 1 42.95	+ 1	+ 3	- 4	11	23.10	31.4
	10		15.1733	25.1353	+ 14	- .7	- .1	40 40 35.18	- 4 11.90	+ 3	- 13	- 7	6	23.17	
	11		7.2520 ⁱⁱ	34.1707 ^{iv}	+ 43	-1.8	-1.8	40 25 2.06	+11 20.68	+1.23	- 51	+20	6	23.72	31.8
Nov	27	IV 1	26.9593	14.2100	+ 63	- .3	- .6	40 41 45.70	- 5 22.49	+ 4	- 12	-10	7	23.10	32.0
		R	20.6747	22.8660	+ 34	+1.4	+1.5	40 37 17.58	- 55.49	+ 1	+ 41	- 2	13	22.62	47.7
	2		21.6617	19.9877	+ 11	+ .4	+1.5	40 37 4.90	- 42.35	+ 1	+ 25	- 1	11	22.91	
	3		28.2627	12.4797	+ 48	- .1	+ .1	40 29 43.66	+ 6 39.15	- 5	- 0	+12	7	22.95	47.2 ^a
	4		16.4277	22.2807	- 34	+1.1	+ .5	40 38 49.67	- 2 27.89	+ 2	+ 24	- 5	10	22.09	
	5		28.7120 ^{iv}	12.5610 ⁱⁱ	- 22	+ .8	+ .7	40 29 32.48	+ 6 48.27	+1.27	+ 22	+12	6	22.42	48.0
	6		11.0093 ⁱⁱ	29.5523 ^{iv}	- 2	+2.5	+1.1	40 28 31.98	+ 7 48.80	+1.26	+ 54	+13	5	22.76	47.6
	7		27.7573 ^{iv}	13.5943 ⁱⁱ	- 36	- .9	+ .3	40 30 22.96	+ 5 57.98	+1.27	- 10	+10	6	22.27	
	8		12.4017	29.2143	+116	+ .4	+ .3	40 43 28.04	- 7 5.35	+ 5	+ 10	-13	7	22.78	47.2
	9		22.4877	18.4293	+ 16	+1.6	+1.5	40 33 6.00	- 1 42.65	+ 1	+ 45	- 4	11	23.88	*
	10		25.2593	15.2620	+ 22	+1.3	+ .5	40 40 35.25	- 4 12.81	+ 3	+ 27	- 7	6	22.73	46.0
	11		33.3337 ^{iv}	6.4587 ⁱⁱ	- 8	+1.2	+1.2	40 25 2.14	+11 19.44	+1.23	+ 34	+20	6	23.41	
	12		14.3010	27.0530	+ 74	- .5	- .3	40 41 45.78	- 5 22.59	+ 4	- 12	-10	7	23.08	46.0

* Hurried.

1894.	Star.	P	Micrometer.		Levels.			$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther- mom.
					C	A	B		Micrometer.	δ	l	r	Mer		
Nov								$\begin{smallmatrix} \circ & / & '' \\ 40 & 42 & 45.60 \end{smallmatrix}$						$\begin{smallmatrix} \circ & / & '' \\ 40 & 36 & 23.48 \end{smallmatrix}$	$\begin{smallmatrix} \circ \\ 41.4 \end{smallmatrix}$
27	I	1	R	13.1997	28.3063	+100	+ .4	.0	— 6 22.18	+ 5	+ 6	—13	8	23.25	41.3
		2		17.2260	21.5887	— 25	— .5	+ .1	+ 1 50.24	— 1	— 6	+ 4	9	23.48	40.8
Nov		3		13.0837	27.0707	+ 9	— .5	—1.1	+ 5 53.65	+ 4	— 22	—10	6	22.71	31.0
28	IV	1	D	21.6647	19.4820	+ 10	+1.0	+ .6	— 55.21	+ 1	+ 23	— 2	13	22.49	
		2		19.6687	21.3497	+ 6	.0	.0	— 42.51	+ 1	— 0	— 1	11		
		3		12.6363	28.4220	+ 73	+ .2	— .1	+ 6 39.28	— 5	+ 1	+12	7	23.08	30.6
		4		21.6667	15.8277	— 64	+ .3	+ .5	— 2 27.46	+ 2	+ 11	— 5	10	22.40	
		5		11.0777 ⁱⁱ	27.3047 ^{iv}	+ 28	+3.5	+2.7	+ 6 50.33	+1.27	+ 90	+12	6	[25.17]	
		6		29.7147 ^{iv}	11.1400 ⁱⁱ	— 3	.0	+1.1	+ 7 49.60	+1.26	+ 14	+13	5	23.19	30.0
		7		12.8593 ⁱⁱ	27.0350 ^{iv}	+ 1	+2.0	+ .8	+ 5 58.37	+1.27	+ 42	+10	6	23.22	
		8		28.3753	11.5720	— 1	— .1	— .5	— 7 4.82	+ 5	— 8	—13	7	23.18	29.4
		9		19.7630	23.8430	+ 65	—1.1	+ .1	— 1 43.36	+ 1	— 16	— 4	11	22.62	29.3
		10		14.8387	24.8373	— 13	— .2	+ .7	+ 4 12.75	+ 3	+ 6	— 7	6	22.66	29.0
		11		7.3597 ⁱⁱ	34.2490 ^{iv}	— 49	+1.2	— .8	+11 19.95	+1.23	+ 9	+20	6	23.75	
		12		26.5347	13.7597	+ 17	+2.6	+1.9	— 5 23.02	+ 4	+ 66	—10	7	23.52	29.0
Nov															
29	IV	1	R	30.7197	22.8857	+ 34	.0	— .7	— 54.85	+ 1	— 9	— 2	13	22.72	28.6
		2		21.5377	19.8917	+ 9	+1.0	— .1	— 41.64	+ 1	+ 14	— 1	11	23.48	
		3		28.4770	12.6757	+ 71	— .5	+ .4	+ 6 39.67	— 5	— 3	+12	7	23.38	27.8
		4		17.2020	23.9917	+ 35	—2.1	—1.4	— 2 26.47	+ 2	— 51	— 5	10	22.77	
		5		28.5883 ^{iv}	12.4117 ⁱⁱ	— 17	+ .4	+ .9	+ 6 48.94	+1.27	+ 17	+12	6	23.06	
		6		11.0840 ⁱⁱ	29.6807 ^{iv}	— 3	—1.2	—1.6	+ 7 50.16	+1.26	— 39	+13	5	23.23	27.4
		7		26.5580 ^{iv}	12 3760 ⁱⁱ	+ 28	+ .7	+ .5	+ 5 58.62	+1.27	+ 18	+10	6	23.26	
		8		12.4497	29.2210	+120	—1.5	.0	— 7 4.32	+ 5	— 24	—13	7	23.56	
		9		22.9857	18.9147	+ 34	+1.6	+ .7	— 1 43.01	+ 1	+ 35	— 4	11	23.55	27.3
		10		24.9340	14.9663	— 3	+1.6	.0	— 4 12.01	+ 3	+ 26	— 7	6	23.66	
		11		33.3627 ^{iv}	6.4703 ⁱⁱ	— 4	—1.7	— .4	+11 19.89	+1.23	— 32	+20	6	23.36	26.8
Dec.		12		14.2643	27.0357	+ 70	— .1	+ .3	— 5 23.07	+ 4	+ 3	—10	7	22.93	
3	IV	3	D	12.4063	28.2207	+ 43	+ .3	+ .5	+ 6 39.93	— 5	+ 11	+12	7	23.56	35.4
		4		22.4830	16.6803	— 21	—1.3	— .6	+ 2 26.65	+ 2	— 28	— 5	10	22.67	
		5		11.9337 ⁱⁱ	28.1047 ^{iv}	0	+1.1	+1.4	+ 6 48.84	+1.27	+ 35	+12	6	22.98	35.4
		6		29.9897 ^{iv}	11.4100 ⁱⁱ	— 8	+ .2	+1.8	+ 7 49.72	+1.26	+ 25	+13	5	23.34	34.8
		7		12.5637 ⁱⁱ	26.7437 ^{iv}	+ 18	+ .6	— .2	+ 5 58.55	+1.27	+ 6	+10	6	23.01	
		8		29.6850	12.8897	+190	+3.0	+ .5	— 7 5.10	+ 5	+ 55	—13	7	23.58	
		9		17.6487	21.7300	— 12	+ .3	+1.0	+ 1 43.15	+ 1	+ 18	— 4	11	23.34	34.6
		10		15.4880	25.4813	+ 43	+1.3	+1.9	— 4 12.76	+ 3	+ 45	— 7	6	23.23	35.4
		11		6.9557 ⁱⁱ	33.8453 ^{iv}	+ 26	— .3	—1.0	+11 19.90	+1.23	— 17	+20	6	23.69	35.2
		12		26.7077	13.8920	+ 34	+2.6	+2.1	— 5 24.10	+ 4	+ 68	—10	7	22.77	
	I	1	D	26.5607	11.4043	—136	+ .4	+ .2	+ 6 22.85	+ 5	+ 9	—13	8	23.54	30.0
		2		21.7547	17.4307	— 16	—1.9	—1.1	+ 1 49.28	— 1	— 44	+ 4	9	22.54	
		3		26.6410	12.6173	— 46	+ .6	— .4	— 5 54.44	+ 4	+ 4	—10	6	23.60	30.5
		4		17.8490	21.1270	— 16	+ .8	+1.8	— 1 22.83	+ 1	+ 35	— 3	7	23.26	30.5
		5		16.4910	25.1323	— 61	— .7	— .6	+ 3 38.63	— 3	— 19	+ 7	7	23.92	30.3
		6		23.6993	16.6310	+ 10	—1.4	— .3	+ 2 58.73	— 2	— 26	+ 5	6	23.15	
		7		27.4757	11.6927	— 59	— .2	— .9	+ 6 38.88	+ 5	— 14	—12	7	23.94	
		8		23.8970	16.5873	0	—1.5	— .7	+ 2 52.16	— 2	— 33	+ 5	6	23.32	29.9
		9		21.6123	16.6993	— 39	— .8	—1.0	— 2 4.11	+ 2	— 25	— 4	7	22.90	
Dec.		10		8.6503 ⁱⁱ	30.5260 ^{iv}	— 6	— .1	— .6	+ 9 13.05	+1.25	— 9	+20	9	23.35	30.0
4	IV	2	D	18.3543	20.0010	— 12	—1.4	— .6	+ 41.60	+ 1	— 30	— 1	11	22.69	36.4
		3	R	29.8337	14.0693	+270	+2.0	+2.0	+ 6 39.24	— 5	+ 57	+12	7	23.23	35.9
		4		18.8190	24.6157	+ 87	—2.8	—1.2	+ 2 26.77	+ 2	— 60	— 5	10	22.14	35.4
		5		27.1510 ^{iv}	10.9887 ⁱⁱ	+ 32	+1.1	+ .7	+ 6 48.70	+1.26	+ 27	+12	6	22.67	
		6		10.8067 ⁱⁱ	29.3860 ^{iv}	0	+ .8	— .2	+ 7 49.73	+1.25	+ 8	+13	5	23.10	35.0
		7		26.8930 ^{iv}	12.6967 ⁱⁱ	+ 11	—1.3	.0	+ 5 58.94	+1.26	— 21	+10	6	23.06	34.7
		8		11.1157	27.9217	— 73	— .3	.0	— 7 4.71	+ 5	— 5	—13	7	23.33	34.4
		9		20.9740	16.9043	— 39	— .3	— .3	— 1 42.79	+ 1	— 9	— 4	11	23.41	

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.		Ther- mom.
						A	B		Micrometer.	δ	l	r	Mer			
Dec.																
4	IV 10 R		24.2917	14.3150	- 60	+ .8	+ .7	40 40 35.51	- 4 12.08	+ 3	+ 22	- 7	6	40 36 23.67	33.9	
	11		32.8613 ^{iv}	5.9793 ⁱⁱ	- 34	-1.1	-1.2	40 25 2.47	+11 19.55	+1.23	- 33	+20	6	23.18	33.8	
	12		13.3743	26.1567	- 27	-1.2	-1.2	40 41 46.19	- 5 23.10	+ 4	- 34	-10	7	22.76		
	I 1 R		19.6447 ^{iv}	34.8273 ⁱⁱ	-366	+ .9	- .5	40 42 46.41	- 6 22.93	+ 5	+ 8	-13	8	23.56	27.8	
	2		18.3407	22.6983	+ 19	-2.8	-2.8	40 34 33.69	+ 1 50.22	- 1	- 80	+ 4	9	23.23		
	3		12.5507	26.5827	- 53	-2.4	-2.1	40 42 18.12	- 5 54.63	+ 4	- 65	-10	6	22.84		
	4		21.8250	18.5843	+ 5	+ .2	- .8	40 37 45.80	- 1 21.94	+ 1	- 7	- 3	7	23.84	28.7	
	5		24.6377	16.0233	+ 25	-1.2	+ 1	40 32 45.43	+ 3 37.86	- 3	- 13	+ 7	7	23.27		
	6		16.2747	23.3473	- 11	- .2	.0	40 33 24.69	+ 2 58.78	- 2	- 3	+ 5	6	23.53		
	7		12.9923	28.7483	+121	-3.2	-1.2	40 43 2.95	- 6 38.65	+ 5	- 66	-12	7	23.64	27.7	
	8		16.5373	23.3507	- 5	.0	+ .2	40 33 31.48	+ 2 52.25	- 2	+ 2	+ 5	6	23.84		
	9		17.9533	22.8873	+ 19	+ .3	+ .4	40 38 27.28	- 2 4.79	+ 2	+ 10	- 4	7	22.64	28.0	
Dec.	10		31.8800 ^{iv}	9.9940 ⁱⁱ	+ 16	-1.2	- .3	40 27 8.90	+ 9 13.37	+1.24	- 23	+20	9	23.57		
5	IV 2 D		18.1143	19.7503	- 15	+1.4	+ 4	40 37 4.37	- 41.32	+ 1	+ 27	- 1	11	23.43	32.4	
	3		26.1890	27.1013	-111	+ .5	- .5	40 29 43.16	+ 6 40.22	- 5	+ 1	+12	7	23.53		
	4		20.7427	14.9380	-108	- .9	- .8	40 38 49.35	- 2 26.48	+ 2	- 24	- 5	10	22.70	31.8	
	5		11.7123 ⁱⁱ	27.9053 ^{iv}	+ 7	+ .1	+ .3	40 29 32.16	+ 6 49.41	+1.26	+ 5	+12	6	23.06		
	6		29.7927 ^{iv}	11.2127 ⁱⁱ	- 4	+ .9	+1.6	40 28 31.78	+ 7 49.74	+1.25	+ 34	+13	5	23.29		
	7		12.7483 ⁱⁱ	26.9417 ^{iv}	+ 8	+ .9	.0	40 30 22.84	+ 5 58.86	+1.26	+ 15	+10	6	23.27		
	8		28.8440	12.0473	+ 62	+1.5	+ .8	40 43 28.04	- 7 4.82	+ 5	+ 34	-13	7	23.55	33.0	
	9		17.8370	21.9350	- 4	- .6	-1.0	40 38 6.17	- 1 43.60	+ 1	- 22	- 4	11	22.43		
	10		14.2147	24.2123	- 69	.0	+ .1	40 40 35.48	- 4 12.59	+ 3	+ 1	- 7	6	22.92	33.0	
	11		6.1267	33.0233	- 28	+ .3	-1.0	40 25 2.45	+11 19.94	+1.22	- 7	+20	6	23.80		
	12		27.9490	14.2660	+ 74	+ .1	- .8	40 41 46.18	- 5 23.37	+ 4	- 8	-10	7	22.74	33.0	
	I 1 D		26.1890	11.0167	-188	-1.5	-1.1	40 42 46.52	- 6 23.12	+ 5	- 38	-13	8	23.02	28.8	
	2		20.8883	16.5693	- 49	- .7	.0	40 34 33.79	+ 1 49.06	- 1	- 11	+ 4	9	22.86		
	3		27.8253	13.7760	+100	+2.6	+ .8	40 42 18.22	- 5 55.45	+ 4	+ 52	-10	6	23.29		
	4		17.8697	21.1373	- 16	-1.9	-1.5	40 37 45.88	- 1 22.57	+ 1	- 49	- 3	7	22.87	29.0	
	5		14.7557	23.3657	- 70	+1.7	+1.0	40 32 45.52	+ 3 37.50	- 3	+ 40	+ 7	7	23.53		
	6		23.8113	16.7520	+ 18	- .7	+ .7	40 33 24.78	+ 2 58.52	- 2	- 2	+ 5	6	23.37		
	7		28.0870	12.2920	+ 17	- .4	+ .4	40 43 3.13	- 6 39.38	+ 5	- 1	-12	7	23.74		
	8		24.0273	17.2507	+ 38	- .5	+ .2	40 33 31.55	- 2 51.42	- 2	- 5	+ 5	6	23.01	29.8	
	9		23.3690	18.4447	+ 40	+1.2	+ .1	40 38 27.34	- 2 4.60	+ 2	+ 21	- 4	7	23.00		
Dec.	10		8.7007 ⁱⁱ	30.5733 ^{iv}	- 6	.0	- .4	40 27 8.95	+ 9 12.97	+1.24	- 5	+20	9	23.40	29.8	
6	IV 2 R		21.1620	19.5133	+ 2	+ .6	- .2	40 37 4.26	- 41.69	+ 1	+ 7	- 1	11	22.75	41.0	
	3		26.9157	11.1173	-138	+1.4	+1.8	40 29 43.05	+ 6 39.07	- 5	+ 45	+12	7	22.71	<i>a</i>	
	4		16.9040	22.7240	- 11	- .3	+ .8	40 38 49.26	- 2 27.12	+ 2	+ 5	- 5	10	22.26	39.8	
	5		28.1230 ^{iv}	11.9470 ⁱⁱ	- 1	+ .9	+ .8	40 29 32.06	+ 6 48.96	+1.26	+ 24	+12	6	22.70	39.4	
	6		10.5157 ⁱⁱ	29.0940 ^{iv}	+ 2	+2.3	+1.2	40 28 31.70	+ 7 49.71	+1.25	+ 52	+13	5	23.36		
	7		26.6153 ^{iv}	12.4407 ⁱⁱ	+ 25	- 6	- .6	40 30 22.77	+ 5 58.43	+1.26	- 17	+10	6	22.45		
	8		12.2377	29.0380	+ 90	- .2	+ .1	40 43 27.98	- 7 4.98	+ 5	- 1	-13	7	22.98	39.4	
	9		22.8540	18.7560	+ 29	+1.9	+ .9	40 38 6.14	- 1 43.68	+ 1	+ 41	- 4	11	22.95		
	10		24.6630	14.6983	- 28	- .5	-1.7	40 40 35.45	- 4 11.86	+ 3	- 29	- 7	6	23.32	38.5	
	11		32.7040 ^{iv}	5.8193 ⁱⁱ	- 46	.0	+ .7	40 25 2.43	+11 19.59	+1.22	+ 9	+20	6	23.59	38.0	
	12		13.0690	25.8323	- 61	-3.5	-2.7	40 41 46.18	- 5 22.53	+ 4	- 90	-10	7	22.76		
	I 2 R		19.5957	23.9017	+ 65	+ .7	+1.0	40 34 33.87	+ 1 49.03	- 1	+ 24	+ 4	9	23.26	32.0	
	3		12.4370	26.4870	- 63	- .8	- .4	40 42 18.31	- 5 55.06	+ 4	- 18	-10	6	23.07		
	4		22.2833	19.0350	- 19	+1.1	.0	40 37 45.98	- 1 22.17	+ 1	+ 18	- 3	7	24.04	32.8	
	5		24.8327	16.2260	+ 38	- .4	+1.3	40 32 45.59	+ 3 37.69	- 3	+ 10	+ 7	7	23.49		
	6		15.4497	22.4907	- 64	+2.3	+2.6	40 33 24.84	+ 2 57.85	- 2	+ 70	+ 5	6	23.48	32.6	
	7		11.3197	27.1473	-108	- .8	+ .9	40 43 3.19	- 6 39.89	+ 5	- 2	-12	7	23.28	32.6	
	8		16.3680	23.1507	- 12	+1.8	+1.3	40 33 31.59	+ 2 51.45	- 2	+ 45	+ 5	6	23.58	32.3	
	9		17.7680	22.6917	+ 10	+ .1	- .3	40 38 27.38	- 2 4.51	+ 2	- 2	- 4	7	22.90		
Dec.	10		29.8953 ^{iv}	8.0533 ⁱⁱ	- 16	+2.8	+1.9	40 27 9.00	+ 9 12.18	+1.24	+ 69	+20	9	23.40	32.4	
23	I 1 D		28.7647	13.5567	+152	.0	.0	40 42 48.20	- 6 24.95	+ 7	0	-13	8	23.27	24.6	

1894.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
Dec. 23	I	D	21.6553	17.3987	-19	-1.3	+ .3	40 34 35.34	+ 1 47.59	- 2	- 17	+ 4	9	40 36 22.87	24.8
			27.7150	13.6193	+ 80	+ .9	- .6	40 42 19.93	- 5 56.64	+ 6	+ 7	- 10	6	23.38	24.2
			17.3803	20.7050	- 27	- 1.2	- .7	40 37 47.41	- 1 24.00	+ 2	- 28	- 3	7	23.19	24.2
			16.6607	25.1977	+ 68	+ .2	- .8	40 32 46.92	+ 3 36.04	- 4	+ 13	+ 7	7	23.19	24.2
			23.5260	16.5450	+ 1	+ 1.0	+ 2.0	40 33 26.16	+ 2 56.53	- 3	+ 41	+ 5	6	23.18	24.2
Dec. 27	I	R	28.7133	12.9107	+ 112	- 1.1	- 1.4	40 43 4.33	- 6 39.88	+ 7	- 35	- 12	7	24.12	24.4
			23.3290	16.5903	- 4	+ .1	+ 1.0	40 33 32.52	+ 2 50.39	- 3	+ 14	+ 5	6	23.13	24.4
			22.5357	17.5483	+ 2	+ 1.3	+ .5	40 38 28.19	- 2 6.12	+ 2	+ 27	- 4	7	22.39	24.4
			9.4103 ^{II}	31.2567 ^{IV}	+ 4	+ 1.9	+ .4	40 27 9.55	+ 9 12.43	+ 1.15	+ 35	+ 20	9	23.77	24.4
			12.6830	27.9537	+ 42	+ 2.9	+ 1.7	40 42 48.58	- 6 26.25	+ 7	+ 68	- 13	8	23.03	17.8
Dec. 28	I	D	18.5187	22.7807	+ 24	.0	- .3	40 34 35.71	+ 1 47.83	- 2	- 4	+ 4	9	23.61	18.4
			13.3250	27.4487	+ 46	+ 1.9	+ 1.5	40 42 20.32	- 5 57.26	+ 6	+ 49	- 10	6	23.57	18.2
			23.7157	20.3860	+ 59	+ 2.4	+ 1.0	40 37 47.78	- 1 24.35	+ 2	+ 51	- 3	7	24.00	18.2
			24.3573	15.8163	+ 6	- 1.9	- .2	40 32 47.25	+ 3 35.99	- 4	- 33	+ 7	7	23.01	18.2
			16.2430	23.2077	- 19	+ 2.1	+ 2.0	40 33 26.49	+ 2 56.07	- 3	+ 59	+ 5	6	23.23	18.2
Dec. 31	I	R	12.9983	28.8710	+ 131	+ .5	+ 2.2	40 43 4.63	- 6 41.70	+ 7	+ 36	- 13	7	23.30	18.3
			17.4077	24.1670	+ 46	+ .7	+ .9	40 33 32.79	+ 2 51.04	- 3	+ 23	+ 5	6	24.14	18.3
			17.9263	22.4287	- 2	- 2.7	- .7	40 38 28.41	- 2 4.29	+ 2	- 52	- 4	7	23.65	18.5
			29.9113 ^{IV}	8.0893 ^{II}	- 16	- 1.1	+ .5	40 27 9.72	+ 9 11.77	+ 1.15	- 11	+ 20	9	22.82	18.5
			27.4567	12.1920	- 24	- .1	+ .9	40 42 48.71	- 6 25.94	+ 7	+ 10	- 13	8	22.89	11.8
Dec. 31	I	D	21.7910	17.5467	- 13	- 1.6	+ .1	40 34 35.84	+ 1 47.29	- 2	- 24	+ 4	9	23.00	12.7
			27.5537	13.5117	+ 65	- .3	- 2.8	40 42 20.48	- 5 55.24	+ 6	- 41	- 10	6	[24.83]	12.7
			22.7480	17.3887	- 14	- 1.0	- 1.8	40 37 47.91	- 1 23.65	+ 2	- 39	- 3	7	23.93	12.7
			15.7367	24.2853	+ 2	+ 1.7	- .1	40 32 47.38	+ 3 36.17	- 4	+ 26	+ 7	7	23.91	12.7
			22.3817	15.3710	- 68	- 3.0	- 1.6	40 33 26.62	+ 2 57.11	- 3	- 68	+ 5	6	23.13	12.7
Dec. 31	I	R	25.7943	9.9383	- 295	+ .5	.0	40 43 4.75	- 6 40.21	+ 7	+ 8	- 12	7	24.64	12.7
			23.6317	16.9030	+ 15	- 1.5	- .3	40 33 32.90	+ 2 50.18	- 3	- 28	+ 5	6	22.88	11.6
			22.7480	17.3887	+ 3	+ 1.9	+ 1.8	40 38 28.51	- 2 15.53	+ 2	+ 53	- 4	7	[13.56]	*
			8.9723 ^{II}	30.8243 ^{IV}	- 1	- .5	- 1.2	40 27 9.81	+ 9 12.56	+ 1.15	- 23	+ 20	9	23.58	12.5
			13.7370	28.9680	+ 185	- .4	- .5	40 42 49.14	- 6 25.61	+ 7	- 13	- 13	8	23.42	19.9
1895 Jan. 1	I	D	18.6120	22.8310	+ 26	+ 2.4	+ 2.2	40 34 36.26	+ 1 46.75	- 2	+ 66	+ 4	9	23.78	18.7
			12.8343	26.9697	- 14	- 2.2	- 1.8	40 42 20.91	- 5 57.40	+ 6	- 58	- 10	6	22.95	18.7
			23.4330	20.0983	+ 52	+ .5	- .1	40 37 48.34	- 1 24.46	+ 2	+ 6	- 3	7	24.00	18.7
			23.3743	14.8313	- 66	- 1.9	- .1	40 32 47.80	+ 3 35.86	- 4	- 32	+ 7	7	23.44	18.8
			15.4587	22.4487	- 64	+ .2	- .2	40 33 27.05	+ 2 56.59	- 3	0	+ 5	6	23.72	18.8
1895 Jan. 4	I	R	12.3710	28.2320	+ 41	- 1.2	.0	40 43 5.15	- 6 41.18	+ 7	- 19	- 12	7	23.80	18.6
			15.7540	22.4727	- 53	+ .6	+ .6	40 33 33.29	+ 2 49.76	- 3	+ 17	+ 5	6	23.30	18.5
			16.2697	21.2537	- 56	- .9	- .3	40 38 28.88	- 2 5.89	+ 2	- 18	- 4	7	22.86	18.5
			32.4810 ^{IV}	10.6620 ^{II}	+ 26	- .4	+ .2	40 27 10.14	+ 9 11.80	+ 1.15	- 4	+ 20	9	23.34	18.6
			27.3300	12.0493	- 41	+ .1	+ .7	40 42 49.26	- 6 26.30	+ 7	+ 10	- 13	8	23.08	19.4
1895 Jan. 4	I	D	17.3180	13.0863	- 197	- 3.9	- .5	40 34 36.38	+ 1 46.51	- 2	- 69	+ 4	9	22.31	19.9
			26.7593	12.5883	- 40	+ 2.7	+ .9	40 42 21.05	- 5 58.24	+ 6	+ 55	- 10	6	23.38	19.9
			17.8997	21.2520	- 13	+ 1.1	- .7	40 37 48.45	- 1 24.74	+ 2	+ 8	- 3	7	23.85	19.9
			15.0610	23.6130	- 50	+ .7	+ .2	40 32 47.90	+ 3 36.13	- 4	+ 13	+ 7	7	24.26	19.9
			23.1087	16.1227	- 24	- .8	- .2	40 33 27.19	+ 2 56.59	- 3	- 15	+ 5	6	23.71	19.9
1895 Jan. 4	I	R	26.6927	10.8273	- 171	- .8	- 1.1	40 43 5.29	- 6 40.75	+ 7	- 27	- 12	7	24.29	19.7
			22.4273	15.7037	- 56	- 1.6	- .5	40 33 33.41	+ 2 49.88	- 3	- 32	+ 5	6	23.05	19.2
			21.8467	16.8377	- 30	+ .1	+ .1	40 38 28.99	- 2 6.59	+ 2	+ 8	- 4	7	22.48	19.1
			7.9410 ^{II}	29.7537 ^{IV}	- 31	+ .4	+ .3	40 27 10.25	+ 9 11.50	+ 1.15	+ 10	+ 20	9	23.29	19.1
			12.7233	28.0137	+ 48	+ 1.2	+ .2	40 42 49.52	- 6 26.77	+ 7	+ 22	- 13	8	22.99	16.9
1895 Jan. 4	I	D	20.9373	25.1270	+ 111	- .6	- 1.6	40 34 36.64	+ 1 46.22	- 2	- 30	+ 4	9	22.67	17.4
			12.8260	26.9897	- 12	- .8	- .4	40 42 21.34	- 5 58.12	+ 6	- 18	- 10	6	23.06	17.4
			22.1183	18.7570	+ 12	- .5	- 1.9	40 37 48.72	- 1 25.03	+ 2	- 32	- 3	7	23.43	17.4
			25.2397	16.7280	+ 72	+ .2	+ 1.1	40 32 48.20	+ 3 35.42	- 4	+ 17	+ 7	7	23.89	17.4
			15.9023	22.8207	- 39	+ 5.8	+ 5.4	40 33 27.48	+ 2 54.85	- 3	+ 1.62	+ 5	6	24.03	17.4

* Definition this evening very poor; work not satisfactory.

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.	
						A	B		Micrometer.	δ	l	r	Mer			
Jan.	4	I	7 R	12.0480	27.9453	0	— .8	+ .3	40 43 5.54	— 6 41.99	+ 7	— 9	— 12	7	40 36 23.48	16.0
			8	16.6873	23.3590	+ 1	+ .9	+ .1	40 33 33.68	+ 2 48.71	— 3	+ 16	+ 5	6	22.63	
			9	17.9463	22.9763	+ 21	— .1	+ .3	40 38 29.24	— 2 7.25	+ 2	+ 2	— 4	7	22.06	
Jan.	10	I	10	32.8960 ^{iv}	11.1133 ⁱⁱ	+ 33	— .3	+ .7	40 27 10.47	+ 9 10.90	+ 1.08	+ 4	+ 20	9	22.78	16.5
11	I	1 D	28.1667	12.8743	+ 68	— .7	— .8	40 42 50.18	— 6 26.87	+ 7	— 21	— 13	8	23.12	34.4	
			2	22.0477	17.8537	— 3	— 1.5	— .2	40 34 37.29	+ 1 46.05	— 2	— 26	+ 4	9	23.19	
			3	27.6940	13.4890	+ 75	+ 3.1	+ 1.7	40 42 22.07	— 5 59.39	+ 6	+ 71	— 10	6	23.41	
			4	17.7473	21.1730	— 17	+ 1.2	+ .2	40 37 49.40	— 1 26.58	+ 2	+ 22	— 3	7	23.10	
			5	15.6443	24.1290	— 7	.0	.0	40 32 48.85	+ 3 34.53	— 4	.0	+ 7	7	23.48	34.1
			6	21.6757	14.7347	— 128	— .8	.0	40 33 28.15	+ 2 55.24	— 3	— 13	+ 5	6	23.34	34.1
			7	27.6503	11.7157	— 46	— .6	+ .7	40 43 6.16	— 6 42.82	+ 7	— 19	— 12	7	23.17	33.9
			8	23.4493	16.7647	+ 5	— .6	+ .3	40 33 34.27	+ 2 49.04	— 3	— 5	+ 5	6	23.34	
			9	22.6323	17.6030	+ 5	+ 1.1	+ 1.9	40 38 29.79	— 2 7.19	+ 2	+ 42	— 4	7	23.07	
Jan.	10	I	2 R	9.0183 ⁱⁱ	30.7967 ^{iv}	— 1	+ 1.1	+ .7	40 27 10.93	+ 9 10.70	+ 1.08	+ 26	+ 20	9	23.26	33.8
14	I	2 R	17.3153	21.4750	— 23	+ .6	.0	40 34 37.69	+ 1 45.13	— 2	+ 9	+ 4	9	23.02	23.1	
			4	22.3587	18.9407	+ 21	+ 1.7	+ .2	40 37 49.83	— 1 26.48	+ 2	+ 30	— 3	6	23.70	22.8
			5	23.5180	15.0660	— 52	— .7	+ .8	40 32 49.28	+ 3 33.59	— 4	— 1	+ 7	7	22.96	
			7	13.4530	29.3813	+ 197	— 1.5	+ .8	40 43 6.58	— 6 43.27	+ 7	— 14	— 12	7	23.19	22.4
			8	16.3900	23.0763	— 17	+ .1	— .5	40 33 34.70	+ 2 49.03	— 3	— 5	+ 5	6	23.76	
			9	17.2883	22.3177	— 9	— 1.9	— .5	40 38 30.20	— 2 7.15	+ 2	— 37	— 4	7	22.73	
Jan.	10	I	10	30.3397 ^{iv}	8.5730 ⁱⁱ	— 8	— .3	+ .4	40 27 11.30	+ 9 10.39	+ 1.08	.0	+ 20	9	23.06	22.4
			1	27.7560	12.4147	+ 10	+ 2.0	+ .7	40 42 50.79	— 6 27.96	+ 7	+ 41	— 13	8	23.26	31.3
			2	22.0300	17.8737	— 2	— .5	.0	40 34 37.86	+ 1 45.09	— 2	— 8	+ 4	9	22.98	31.4
			3	28.0220	13.7917	+ 111	+ 1.6	+ 1.5	40 42 22.61	— 6 0.12	+ 6	+ 45	— 10	6	22.96	
			4	16.3370	19.7907	— 59	+ .8	— .4	40 37 49.86	— 1 27.18	+ 2	+ 8	— 3	7	22.82	31.1
			5	17.3683	25.8183	+ 116	+ 1.0	— .3	40 32 49.50	+ 3 33.97	— 4	+ 12	+ 7	7	23.69	
			6	22.4147	15.5040	— 64	— .1	.0	40 33 28.84	+ 2 54.59	— 3	— 1	+ 5	6	23.50	
			7	26.7190	10.7427	— 181	+ 1.5	+ 1.9	40 43 6.82	— 6 43.53	+ 7	+ 48	— 12	7	23.79	
			8	22.4483	15.8057	— 51	— .5	+ .3	40 33 34.94	+ 2 47.84	— 3	— 5	+ 5	6	22.81	30.6
			9	22.5500	17.4913	+ 1	+ 1.8	+ 2.4	40 38 30.43	— 2 7.92	+ 2	+ 59	— 4	7	23.15	
Jan.	10	I	10	8.6340 ⁱⁱ	30.3773 ^{iv}	— 10	+ 1.6	+ .9	40 27 11.52	+ 9 9.79	+ 1.01	+ 37	+ 20	9	22.98	30.7
			1	10.7857	26.1690	— 206	+ 2.7	+ .9	40 42 50.98	— 6 28.47	+ 7	+ 55	— 13	8	23.08	21.5
			2	18.1623	22.3303	+ 9	— 2.3	— 3.3	40 34 38.10	+ 1 45.42	— 2	— 79	+ 4	9	22.84	
			3	13.0197	27.2393	+ 17	— 3.0	— .7	40 42 22.97	— 5 59.61	+ 6	— 57	— 10	6	22.81	
			4	21.0013	17.5693	— 22	— .4	— 1.8	40 37 50.28	— 1 26.73	+ 2	— 29	— 3	7	23.32	21.5
			5	24.7470	16.2933	+ 38	— 2.7	— .9	40 32 49.74	+ 3 33.86	— 4	— 55	+ 7	7	23.15	21.5
			6	17.0123	23.9127	+ 28	+ .8	— .1	40 33 29.09	+ 2 54.56	— 3	+ 11	+ 5	6	23.84	
			7	12.6543	28.6260	+ 89	— .4	+ 2.1	40 43 6.98	— 6 44.10	+ 7	+ 20	— 12	7	23.10	21.1
			8	16.5393	23.1927	— 10	+ .2	— .3	40 33 35.18	+ 2 48.22	— 3	— 1	+ 5	6	23.47	
			9	18.5667	23.5733	+ 48	— 1.1	— .8	40 38 30.67	— 2 6.72	+ 2	— 27	— 4	7	23.73	
Jan.	10	I	10	31.3033 ^{iv}	9.5243 ⁱⁱ	+ 4	— 2.2	— 1.5	40 27 11.73	+ 9 10.73	+ 1.01	— 54	+ 20	9	23.22	21.3
			1	28.1487	12.8023	— 63	+ 1.4	.0	40 42 51.29	— 6 28.22	+ 7	+ 22	— 13	8	23.31	21.8
			2	19.9607	15.8017	— 78	— 1.1	.0	40 34 38.42	+ 1 44.97	— 2	— 17	+ 40	9	23.69	
			3	27.9597	18.7597	+ 105	+ .8	— .7	40 42 23.32	— 5 59.34	+ 6	+ 4	— 10	6	24.04	
			4	17.0320	20.4847	— 36	— 1.5	— .2	40 37 50.63	— 1 27.22	+ 2	— 26	— 3	7	23.21	
			5	15.8827	24.3203	+ 8	+ .7	+ 1.0	40 32 50.08	+ 3 33.38	— 4	+ 24	+ 7	7	23.80	20.9
			6	23.9107	17.0240	+ 28	— .6	.0	40 33 29.46	+ 2 54.21	— 3	— 9	+ 5	6	23.66	
			7	27.4107	11.4513	— 80	— .2	+ .1	40 43 7.41	— 6 43.36	+ 7	— 2	— 12	7	24.05	21.0
			8	21.6423	14.9897	— 98	— 3.1	— .7	40 33 35.54	+ 2 47.97	— 3	— 59	+ 5	6	23.00	21.0
			9	22.2260	17.1660	— 15	+ .5	.0	40 38 31.01	— 2 7.91	+ 2	+ 8	— 4	7	23.23	20.6
Jan.	10	I	10	9.3280 ⁱⁱ	31.0920 ^{iv}	+ 1	— .4	— 1.9	40 27 12.02	+ 9 10.84	+ 1.01	— 31	+ 20	9	23.35	
			1	12.8830	28.2007	+ 74	+ .1	— .8	40 42 51.40	— 6 27.52	+ 7	— 8	— 13	8	23.82	18.6
			2	19.4427	23.5967	+ 56	— 1.7	— 2.3	40 34 38.54	+ 1 45.18	— 2	— 57	+ 4	9	23.26	
			3	12.4887	26.7293	— 48	— 1.0	— .8	40 42 23.45	— 5 59.98	+ 6	— 26	— 10	6	23.23	
			4	22.7650	19.3170	+ 30	+ 1.1	— .1	40 37 50.76	— 1 27.26	+ 2	+ 16	— 3	7	23.72	18.6

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther. mon.
						A	B		Micrometer.	δ	l	r	Mer		
Jan. 24	I	5 R	23.9523	16.5090	+ 18	-3.0	-1.1	40 32 50.20	+ 3 33.54	- 4	- 62	+ 7	7	40 36 23.22	0
		6	13.9720	20.9187	-156	-4.1	-4.7	40 33 29.59	+ 2 55.26	- 3	-1.26	+ 5	6	23.67	18.5
		7	12.9543	28.9067	+129	-1.2	+ .6	40 43 7.53	- 6 43.71	+ 7	- 12	-12	7	23.72	18.4
		8	15.0560	21.6917	- 95	+ .6	+1.0	40 33 35.67	+ 2 47.56	- 3	+ 22	+ 5	6	23.53	
		9	17.9413	23.0197	- 21	- .6	+ .6	40 38 31.14	- 2 8.36	+ 2	- 2	- 4	7	22.81	
Jan. 27	I	10	31.8540 ^{iv}	10.1080 ⁱⁱ	+ 15	-1.5	- .7	40 27 12.14	+ 9 9.92	+1.01	- 33	+20	9	23.03	18.3
		1	28.6000	13.2353	+124	- .6	- .2	40 42 51.78	- 6 28.84	+ 9	- 12	-13	8	22.86	23.6
		2	23.1777	19.0533	+ 40	- .3	- .0	40 34 38.92	+ 1 44.39	- 2	- 5	+ 4	9	23.37	
		3	32.6637	18.4813	+690	- .0	- .9	40 42 23.87	- 6 0.37	+ 9	- 11	-10	6	23.44	
		4	18.9573	22.4080	+ 22	+ .4	- .2	40 37 51.18	- 1 27.31	+ 2	+ 4	- 3	7	23.97	23.1
		5	15.1823	23.5960	- 53	+ .3	+ .6	40 32 50.63	+ 3 32.62	- 5	+ 12	+ 7	7	23.46	
		6	22.8593	16.0010	- 34	+ .6	+ .9	40 33 30.04	+ 2 53.34	- 4	+ 21	+ 5	6	23.66	
		7	26.0500	10.0343	-275	+ .3	+ .4	40 43 7.97	- 6 44.29	+ 10	+ 10	-13	7	23.82	23.1
		8	22.5777	15.9770	- 40	-1.2	- .1	40 33 36.12	+ 2 46.81	- 4	- 21	+ 5	6	22.79	
		9	21.4150	16.3247	- 53	+ .9	+1.1	40 38 31.58	- 2 8.59	+ 3	+ 28	- 4	7	23.33	
	II	10	8.2177 ⁱⁱ	29.9533 ^{iv}	- 14	+ .2	- .5	40 27 12.55	+ 9 9.59	+ 98	- 3	+20	9	23.38	22.9
		1	15.8943	21.5843	- 64	- .7	- .0	40 38 47.07	- 2 23.72	+ 4	- 11	- 4	6	23.30	19.2
		2	21.5067	17.1023	- 28	- .3	-1.5	40 38 15.13	+ 1 51.30	+ 3	- 24	- 3	6	23.65	
		3	21.0307	17.8680	- 16	- .2	+ .6	40 35 3.66	+ 1 19.93	- 2	+ 4	+ 3	6	23.70	19.5
		4	19.9253	18.4800	- 11	- .0	- .0	40 36 59.48	- 36.52	+ 1	- 0	- 1	7	23.03	19.2
		5	17.9253	17.5993	- 7	+ .4	+ .4	40 36 15.19	+ 8.23	- 0	+ 11	- 0	8	23.61	
		6	32.1860 ^{iv}	9.9473 ⁱⁱ	+ 21	- .9	-1.1	40 45 47.03	- 9 22.40	- 97	- 28	-16	6	23.28	
		7	15.0667	26.2270	+ 63	- .7	- .1	40 41 5.03	- 4 42.37	+ 7	- 12	- 8	6	22.59	19.0
Jan. 29	I	8	7.9793 ⁱⁱ	29.3463 ^{iv}	- 14	+ .5	+2.2	40 27 21.90	+ 9 0.27	+ 98	+ 36	+18	8	23.77	19.4
		1 R	10.7350	26.1497	-209	+1.0	+1.2	40 42 51.97	- 6 29.25	+ 9	+ 31	-13	8	23.07	20.1
Jan. 31	I	2	17.1220	21.2527	- 31	- .5	-1.1	40 34 39.13	+ 1 44.37	- 2	- 22	+ 4	9	23.39	
		1 R	12.0117	27.4050	- 39	+2.0	+ .9	40 42 52.09	- 6 29.15	+ 9	+ 43	-13	8	23.41	15.5
		2	21.4953	25.5917	+128	- .2	- .6	40 34 39.26	+ 1 43.91	- 2	- 10	+ 4	9	23.18	
		3	12.3113	26.5757	- 69	-2.0	- .6	40 42 24.26	- 6 0.53	+ 9	- 39	-10	6	23.39	
		4	22.5010	19.0627	+ 24	-1.5	-2.6	40 37 51.57	- 1 27.00	+ 2	- 57	- 3	7	24.06	
		5	23.6550	15.2493	- 39	- .1	+ .2	40 32 51.04	+ 3 32.43	- 5	+ 1	+ 7	7	23.57	16.1
		6	17.6210	24.4347	+ 60	+2.4	+1.9	40 33 30.49	+ 2 52.45	- 4	+ 63	+ 5	6	23.64	
		7	11.8893	27.8960	- 14	- .4	+ .6	40 43 8.41	- 6 44.72	+ 10	+ 1	-13	7	23.74	16.1
		8	16.4380	23.0180	- 16	+1.1	+ .6	40 33 36.61	+ 2 46.34	- 4	+ 28	+ 5	6	23.30	15.7
		9	17.6633	22.7730	+ 10	+ .8	- .8	40 38 32.06	- 2 9.23	+ 3	+ 3	- 4	7	22.92	
	II	10	30.3100 ^v	8.5940 ⁱⁱ	- 8	- .5	+ .6	40 27 13.01	+ 9 9.11	+ 98	- 0	+20	9	23.39	16.3
		1 R	22.4637	16.7440	- 21	+ .6	+ .2	40 38 46.80	- 2 24.58	+ 4	+ 12	- 4	6	22.40	10.1a
		2	15.8703	20.3123	- 73	+2.8	+2.3	40 38 14.82	+ 1 52.14	+ 3	+ 74	- 3	6	23.48	
		3	18.4393	21.6007	- 2	+1.2	+1.2	40 35 3.29	+ 1 19.94	- 2	+ 35	+ 3	6	23.65	10.7
		4	21.8863	23.3047	+ 32	- .3	+ .8	40 36 59.09	+ 35.95	+ 1	+ 5	- 1	7	23.26	
		5	21.4587	21.7863	+ 5	- .0	- .5	40 36 14.76	+ 8.30	- 0	- 6	- 0	8	23.08	
		6	9.4237 ⁱⁱ	31.5883 ^{iv}	+ 8	-2.5	-3.1	40 45 46.54	- 9 20.49	- 97	- 79	-16	6	24.19	
		7	25.6877	14.5387	+ 9	+ .7	+ .6	40 41 4.47	- 4 41.94	+ 7	+ 18	- 8	6	22.76	10.0
		8	30.5783 ^{iv}	9.2253 ⁱⁱ	- 1	+1.0	+2.3	40 27 21.36	+ 8 59.95	+ 98	+ 45	+18	8	23.00	
		9	22.2980	18.3067	+ 10	- .0	+ .5	40 34 43.05	+ 1 40.95	- 2	+ 2	+ 3	6	24.09	9.7
Feb 2	I	1 D	27.6977	12.3043	- 0	+1.5	+ .9	40 42 52.17	- 6 29.25	+ 9	+ 35	-13	8	23.31	18.2
		2	20.6353	16.5093	- 53	- .6	- .6	40 34 39.36	+ 1 44.20	- 2	- 17	+ 4	9	23.50	
		3	26.3453	12.0487	- 99	+1.9	- .0	40 42 24.37	- 6 1.26	+ 9	+ 30	-10	6	23.46	17.8
		4	15.9030	19.3763	- 72	-2.3	-2.0	40 37 51.69	- 1 27.65	+ 2	- 62	- 3	7	23.48	
		5	17.9807	26.3413	+159	+2.2	+1.7	40 32 51.17	+ 3 31.81	- 5	+ 57	+ 7	7	23.64	17.4
		6	23.3257	16.4673	- 8	-3.3	-1.5	40 33 30.63	+ 2 53.41	- 4	- 72	+ 5	6	23.39	
		7	25.2257	9.1673	-395	- .3	+1.5	40 43 8.55	- 6 45.07	+ 10	+ 14	-13	7	23.66	
		8	22.5727	15.9643	- 42	- .8	- .7	40 33 36.76	+ 2 47.00	- 4	- 22	+ 5	6	23.61	16.0
		9	21.1257	15.9870	- 67	- .2	- .2	40 38 32.22	- 2 9.77	+ 3	- 5	- 4	7	22.46	
		10	7.8630 ⁱⁱ	29.5847 ^{iv}	- 18	- .7	-2.0	40 27 13.15	+ 9 9.23	+ 98	- 36	+20	9	23.29	16.6

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.		Ther- mom.
						A	B		Micrometer.	δ	l	r	Mer			
Feb.																
2	II	1	D	12.2620	17.9823	-246	+1.2	+1.1	40 38 46.67	- 2 24.03	+ 4	+ 33	- 4	6	40 36 23.03	11.4
		2		21.6283	17.2390	- 24	-1.2	- .7	40 38 14.68	- 1 50.93	+ 3	- 28	- 3	6	23.53	
		3		21.3300	18.1550	- 8	-1.7	-1.2	40 35 3.12	+ 1 20.27	- 2	- 43	+ 3	6	23.03	11.5
		4		20.6430	19.2583	- 1	-1.2	.0	40 36 58.91	- 35.01	+ 1	- 19	- 1	7	23.78	11.4
		6		32.3313 ^{iv}	10.1273 ⁱⁱ	+ 24	+1.4	+ .6	40 45 46.33	- 9 21.53	- 97	+ 30	-16	6	24.03	
		7		12.8067	23.9533	-159	-2.7	-1.2	40 41 4.23	- 4 41.46	+ 7	- 59	- 8	6	22.23	11.1
		8		11.9183 ⁱⁱ	33.3260 ^{iv}	+ 32	-2.4	-1.9	40 27 21.12	+ 9 1.41	+ 98	- 63	+18	8	23.14	
		9		18.5373	22.4990	+ 18	- .6	- .8	40 34 42.81	+ 1 40.22	- 2	- 19	+ 3	6	22.91	
Mar.		10		13.3250	29.8420	+228	-1.2	-2.6	40 29 26.74	+ 6 58.24	- 10	- 53	+12	5	[24.52]	9.9*
3	I	1	R	12.2473	27.6790	- 4	+ .6	-1.0	40 42 53.57	- 6 30.21	+ 9	- 3	-13	8	23.37	36.8
		2		18.6880	22.7387	+ 25	- .6	-1.4	40 34 41.01	+ 1 42.49	- 2	- 27	+ 4	9	23.34	
		3		12.5803	26.9643	- 28	- .7	+ .4	40 42 26.32	- 6 3.65	+ 9	- 6	-10	6	22.66	
		4		22.3317	18.7803	+ 17	+1.4	+ .4	40 37 53.74	- 1 29.85	+ 2	+ 27	- 3	7	24.22	36.6
		5		24.4600	16.1720	+ 23	+ .7	+1.7	40 32 53.38	+ 3 29.63	- 5	+ 33	+ 7	7	23.43	
		6		15.5470	22.3117	- 65	- .4	- .8	40 33 33.12	+ 2 50.89	- 4	- 16	+ 5	6	23.92	
		7		12.3530	28.4517	+ 55	-1.2	+ .2	40 43 11.05	- 6 47.22	+ 10	- 17	-13	7	23.70	36.4
		8		16.4237	22.9050	- 21	+ .4	+ .4	40 33 39.63	+ 2 43.84	- 4	+ 11	+ 5	6	23.65	35.9
		9		17.9977	23.2097	+ 28	+ .4	+ .4	40 38 35.12	- 2 11.87	+ 3	+ 11	- 4	7	23.42	
Mar.		10		32.6640 ^{iv}	9.0860 ⁱⁱ	+ 27	+ .2	+ .9	40 27 15.90	+ 9 5.71	+ 98	+ 14	+20	9	23.02	35.3
5	I	1	D	27.3560	11.9300	- 47	+ .2	- .9	40 42 53.60	- 6 29.95	+ 9	- 8	-13	8	23.61	27.3
		2		21.7860	17.7160	- 9	-3.4	-2.2	40 34 41.06	+ 1 42.89	-	- 82	+ 4	9	23.24	
		3		27.8133	13.4457	+ 78	+2.9	+1.0	40 42 26.39	- 6 3.51	+ 9	+ 59	-10	6	23.52	
		4		17.3173	20.9617	- 28	-1.3	-1.4	40 37 53.82	- 1 32.08	+ 2	- 39	- 3	7	[31.41]	†
		5		15.8497	23.6647	- 35	+ .7	+ .2	40 32 53.46	+ 3 30.17	- 5	+ 13	+ 7	7	23.85	27.0
		6		22.4010	15.6770	- 56	.0	+ .6	40 33 33.22	+ 2 49.89	- 4	+ 7	+ 5	6	23.25	
		7		28.1730	12.0843	+ 15	+ .9	.0	40 43 11.15	- 6 46.87	+ 10	+ 14	-13	7	24.46	26.7
Mar.		10		8.8650 ⁱⁱ	30.4510 ^{iv}	- 3	+1.1	.0	40 27 16.04	+ 9 5.83	+ 98	+ 17	+20	9	23.31	26.7
6	I	1	R	12.5470	28.0190	+ 37	+1.7	+1.2	40 42 53.64	- 6 31.33	+ 9	+ 43	-13	8	22.78	34.9
		3		12.6267	26.9953	- 26	- .3	+ .6	40 42 26.33	- 6 3.27	+ 9	+ 2	-10	6	23.13	
		4		23.3123	19.7583	+ 47	-1.6	-1.5	40 37 53.89	- 1 29.99	+ 2	- 44	- 3	7	23.52	34.8
Mar.		9	I	25.0603	9.5817	-362	- .1	- .1	40 42 53.78	- 6 30.49	+ 9	- 3	-13	8	23.30	32.4
		2		21.6117	17.5830	- 16	-1.0	-1.4	40 34 41.28	+ 1 41.83	- 2	- 34	+ 4	9	22.88	
		3		26.3027	11.9287	-112	+1.5	+1.2	40 42 26.62	- 6 3.19	+ 9	+ 39	-10	6	23.87	
		4		14.8247	18.4367	-106	+1.2	+ .6	40 37 54.09	- 1 31.07	+ 2	+ 27	- 3	7	23.35	
		5		16.3457	24.6377	+ 33	+ .5	.0	40 32 53.76	+ 3 29.76	- 5	+ 8	+ 7	7	23.69	32.6
		6		23.5247	16.7937	+ 9	-1.8	- .8	40 33 33.56	+ 2 50.23	- 4	- 39	+ 5	6	23.47	
		7		27.8980	11.7807	- 23	+ .4	- .1	40 43 11.51	- 6 47.50	+ 10	+ 5	-13	7	24.10	32.9
		8		23.5583	17.1097	+ 19	- .9	+ .6	40 33 40.17	+ 2 43.11	- 4	- 7	+ 5	6	23.28	
		9		22.3167	17.0960	- 14	- .4	+ .5	40 38 35.68	- 2 11.98	+ 3	0	- 4	7	23.76	
Mar.		10		9.3283 ⁱⁱ	30.8897 ^{iv}	+ 1	+1.1	- .7	40 27 16.33	+ 9 5.22	+ 98	+ 8	+19	9	22.89	33.4
10	I	1	R	11.4433	26.9020	-113	- .1	-1.0	40 42 53.80	- 6 30.61	+ 9	- 18	-13	8	23.05	45.8
		2		18.2213	22.2463	+ 8	-1.2	-1.0	40 34 41.30	+ 1 41.80	- 2	- 32	+ 4	9	22.89	
		3		12.5077	26.8867	- 40	+ .6	+ .8	40 42 26.67	- 6 3.50	+ 9	+ 19	-10	6	23.41	44.9
		4		23.2097	19.6057	+ 43	+1.0	+ .2	40 37 54.14	- 1 31.24	+ 2	+ 18	- 3	7	23.14	
		6		18.6473	25.3220	+115	+3.3	+2.2	40 33 33.64	+ 2 49.07	- 4	+ 81	+ 5	6	23.59	45.5
Mar.		14	I	24.6397	20.6043	+ 91	+ .1	+ .2	40 34 41.30	+ 1 42.27	- 2	+ 4	+ 4	9	23.72	26.9a
		3		27.1607	12.7487	- 7	+1.8	+1.8	40 42 26.63	- 6 4.41	+ 9	+ 52	-10	6	22.79	
		4		17.1740	20.8133	- 33	-1.0	+ .2	40 37 54.14	- 1 31.94	+ 2	+ 18	- 3	7	22.44	26.9
16	II	1	R	22.4267	16.6587	- 24	+ .5	+ .9	40 38 48.23	- 2 25.79	+ 4	+ 19	- 4	6	22.69	26.0
		2		17.2900	21.7560	- 19	+ .5	+1.5	40 39 16.00	- 1 52.88	+ 3	+ 27	- 3	6	23.45	
		3		18.6987	21.8340	+ 6	+1.0	+1.2	40 35 3.81	+ 1 19.30	- 2	+ 31	+ 3	6	23.49	25.9
		4		20.0117	21.4213	+ 8	-2.3	- .5	40 36 59.17	- 35.66	+ 1	- 44	- 1	7	23.14	
		5		22.0350	22.3830	+ 8	+ .7	+ .1	40 36 14.36	+ 8.82	- 0	+ 12	0	8	23.38	
		6		12.1123 ⁱⁱ	34.2917 ^{iv}	+ 63	-1.3	- .4	40 45 46.06	- 9 21.00	- 97	- 26	-16	6	23.73	25.6
		7		25.4823	14.3967	- 4	+ .4	-1.3	40 41 3.31	- 4 40.31	+ 7	- 10	- 8	6	22.95	

* Observation unsatisfactory.

† Light bad; observation hurried.

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
Mar.	16	II 8	R	30.4617	9.0060	— 2	—1.7	— .6	40 27 19.88	+ 9 2.54	+ 98	— 35	+18 8	40 36 23.31	26.0
		9		22.4250	18.8803	+ 14	— .8	— .8	40 34 41.25	+ 1 42.31	— 2	— 23	+ 3 6	23.40	
Mar.	17	I 10		28.0770	11.5073	— 31	—2.3	—1.5	40 29 24.64	+ 6 58.92	— 10	— 56	+12 6	23.08	25.9
		3	R	12.6167	27.0033	— 7	+1.4	+1.6	40 42 26.60	— 6 3.77	+ 9	+ 43	—10 6	23.31	33.5
		4		21.3403	17.7350	— 15	+1.9	+ .5	40 37 54.13	— 1 31.13	+ 2	+ 37	— 3 7	23.43	
		5		24.7830	16.5123	+ 45	—1.0	— .4	40 32 53.88	+ 3 29.25	— 5	— 21	+ 7 7	23.01	
		6		17.2957	23.9987	+ 38	+ .2	+1.0	40 33 33.76	+ 2 49.59	— 4	+ 16	+ 5 6	23.58	33.1
		7		11.8850	28.0240	— 8	—1.0	.0	40 43 11.74	+ 6 48.08	+ 10	— 16	—13 7	23.54	32.6
		8		17.2843	23.7133	+ 29	+1.3	+ .5	40 33 40.56	+ 2 42.64	— 4	+ 27	+ 5 6	23.54	32.4
		9		16.9730	22.2447	— 17	— .9	.0	40 38 36.10	— 2 13.26	+ 3	— 14	— 4 7	22.76	
		10		31.6627 ^{iv}	10.1143 ⁱⁱ	+ 11	— .6	+ .5	40 27 16.88	+ 9 4.92	+ 98	— 3	+20 9	23.04	31.8
		II 1	D	15.2007	20.9533	— 97	+ .9	+1.0	40 38 43.36	— 2 25.22	+ 4	+ 27	— 4 6	23.47	28.6
		2		21.4597	17.0043	— 30	+ .4	.0	40 38 16.13	— 1 52.59	+ 3	+ 6	— 3 6	23.66	
		3		20.9570	17.8377	— 17	+ .4	+ .2	40 35 3.94	+ 1 18.83	— 2	+ 9	+ 3 6	22.93	28.8
		4		23.4290	21.9887	+ 35	+ .9	+ .7	40 36 59.28	— 36.51	+ 1	+ 23	— 1 7	23.07	
		5		20.9400	20.6390	+ 2	+1.8	+1.1	40 36 14.46	+ 7.62	— 0	+ 43	0 8	22.59	
		6		30.8943 ^{iv}	8.6570 ⁱⁱ	— 5	+1.7	+2.1	40 45 46.17	— 9 22.30	— 97	+ 54	—16 6	23.34	
		7		13.3703	24.4960	—101	+ .8	+1.3	40 41 3.41	+ 4 41.08	+ 7	+ 29	— 8 6	22.67	28.9
		8		8.3517 ⁱⁱ	29.7993 ^{iv}	— 11	+2.1	.0	40 27 19.96	+ 9 2.31	+ 98	+ 33	+18 8	23.84	
		9		18.1837	22.2187	+ 7	+1.7	+ .3	40 34 41.34	+ 1 42.05	— 2	+ 32	+ 3 6	23.78	
Mar.	18	I 10		11.8173	28.3390	+ 10	+2.6	+1.8	40 29 24.72	+ 6 57.81	— 10	+ 64	+12 6	23.25	30.2
		3	D	28.0747	13.7240	+112	+1.0	— .1	40 42 26.60	— 6 3.17	+ 9	+ 14	—10 6	23.62	38.5
		4		16.9647	20.5643	— 37	+ .7	+ .9	40 37 54.14	— 1 30.93	+ 2	+ 22	— 3 7	23.49	
		5		17.3750	25.6083	+107	+ .1	+ .6	40 32 53.89	+ 3 28.46	— 5	+ 7	+ 7 7	22.51	*
		6		23.7020	16.9940	+ 22	— .1	+ 1.	40 33 33.78	+ 2 49.68	— 4	0	+ 5 6	23.53	
		7		29.4277	13.3203	+192	+ .1	— .3	40 43 11.76	— 6 47.79	+ 10	— 2	—13 7	23.99	37.9
		8		23.1690	16.7407	— 4	— .7	+ .2	40 33 40.60	+ 2 42.54	— 4	+ 8	+ 5 6	23.29	37.7
		9		23.7880	18.5453	+ 54	— .6	— .7	40 38 36.14	— 2 12.71	+ 3	— 5	— 4 7	23.44	
		10		9.2433 ⁱⁱ	30.7753 ^{iv}	0	+2.3	+ .7	40 27 16.92	+ 9 4.47	+ 98	+ 46	+20 9	23.12	
		II 1	R	23.7623	18.0213	+ 46	+ .9	+ .2	40 38 43.48	— 2 25.29	+ 4	+ 17	— 4 6	23.42	33.1
		2		17.1533	21.6187	— 26	+ .4	— .3	40 38 16.25	— 1 52.85	+ 3	+ 2	— 3 6	23.48	
		3		19.3067	22.4300	+ 24	+1.5	+1.8	40 35 4.05	+ 1 19.04	— 2	+ 47	+ 3 6	23.63	32.6
		4		21.4093	22.8347	+ 28	—1.8	— .6	40 36 59.38	— 36.11	+ 1	— 36	— 1 7	22.98	
		5		21.4500	21.7903	+ 6	+ .6	+ .4	40 36 14.54	+ 8.62	— 0	+ 14	0 8	23.38	
		7		25.2077	14.1203	— 32	— .3	+ .1	40 41 3.49	— 4 40.28	+ 7	— 3	— 8 6	23.23	32.4
		8		32.0523 ^{iv}	10.6267 ⁱⁱ	+ 16	+1.1	+1.9	40 27 20.04	+ 9 1.82	+ 98	+ 42	+18 8	23.52	
		9		20.4513	16.4120	— 56	+ .2	+ .6	40 34 41.41	+ 1 42.00	— 2	+ 10	+ 3 6	23.58	
Mar.	19	I 10		28.7230	12.1987	+ 66	+ .4	+ .1	40 29 24.80	+ 6 58.01	— 10	+ 8	+12 6	22.97	31.8
		3	R	12.0263	26.4170	— 99	+1.5	+ .8	40 42 26.54	— 6 3.64	+ 9	+ 34	—10 6	23.29	39.8
		4		23.3787	19.7793	+ 51	+1.6	+ .7	40 37 54.15	— 1 31.15	+ 2	+ 35	— 3 7	23.41	39.8
		5		25.6827	17.4147	+112	—1.0	+ .3	40 32 53.91	+ 3 29.35	— 5	— 12	+ 7 7	23.23	
		6		18.2350	24.9093	+ 91	+2.9	+1.7	40 33 33.82	+ 2 49.00	— 4	+ 68	+ 5 6	23.57	
		7		11.7497	27.8927	— 25	+ .5	+ .5	40 43 11.81	+ 6 48.14	+ 10	+ 16	—13 7	23.87	39.4
		8		16.6220	23.0667	— 11	+ .1	— .5	40 33 40.65	+ 2 42.94	— 4	— 6	+ 5 6	23.60	38.4
		9		18.0033	23.2800	+ 31	+1.9	+1.8	40 38 36.21	— 2 13.51	+ 3	+ 53	— 4 7	23.29	
Mar.	21	I 10		31.7987 ^{iv}	10.2510 ⁱⁱ	+ 13	— .8	+ .4	40 27 16.98	+ 9 4.90	+ 98	— 8	+19 9	23.06	38.1
		5	D	15.1410	23.4293	— 53	.0	— .2	40 32 53.96	+ 3 29.45	— 5	— 2	+ 7 7	23.48	35.4
		6		22.7027	16.0333	— 38	+1.8	+2.3	40 33 33.92	+ 2 48.55	— 4	+ 58	+ 5 6	23.12	
		7		27.9310	11.7730	— 25	— .2	+ .8	40 43 11.92	— 6 48.52	+ 10	— 13	+ 7 7	23.51	
		8		24.2203	17.8237	+ 58	+ .9	+2.0	40 33 40.79	+ 2 41.90	— 4	+ 40	+ 5 6	23.16	34.4
		9		22.1357	16.8437	— 24	+1.1	+ .6	40 33 36.36	— 2 13.76	+ 3	+ 25	— 4 7	22.91	
		10		8.7490 ⁱⁱ	30.2743 ^{iv}	— 6	+2.5	+1.9	40 27 17.14	+ 9 4.29	+ 98	+ 64	+19 9	23.33	34.5
		II 1	D	16.7303	22.5320	— 21	+ .8	+2.2	40 38 48.87	— 2 26.65	+ 4	+ 41	— 4 6	22.69	28.4
		2		22.2537	17.7503	— 0	+1.9	+1.1	40 38 16.63	— 1 53.88	+ 3	+ 44	— 3 6	23.25	
		3		22.3690	19.2720	— 23	+ .3	+1.1	40 35 4.39	+ 1 18.37	— 2	+ 19	+ 3 6	23.02	28.3

* Probably wrong star.

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.	
						A	B		Micrometer.	δ	l	r	Mer			
Mar. 21	II	4	D	22.4203	20.9437	+ 22	+ .6	+ .8	40 36 59.67	- 37.89	+ 1	+ 19	- 1	7	40 36 22.54	27.8
		5		20.0230	19.6970	- 1	-1.4	-1.1	40 36 14.80	+ 8.24	- 0	- 36	0	8	22.76	27.6
		6		31.0887 ^{iv}	8.8497 ⁱⁱ	- 2	- .5	-1.2	40 45 46.56	- 9 22.35	- 97	- 23	-16	6	22.91	
		7		13.9030	25.0160	- 53	- .3	.0	40 41 3.75	- 4 40.88	+ 7	- 5	- 8	6	22.87	
		8		8.0923 ⁱⁱ	29.5163 ^{iv}	- 14	- .4	+ .2	40 27 20.24	+ 9 1.71	+ 98	- 4	+18	8	23.15	
Mar. 22	II	9		18.1470	22.1473	+ 5	+2.0	+ .4	40 34 41.62	+ 1 41.17	- 2	+ 37	+ 3	6	23.23	
		10		11.8230	28.3453	+ 11	+1.5	- .1	40 29 25.00	+ 6 57.82	- 10	+ 22	+12	6	23.12	27.6
		1	R	22.4517	16.6837	- 22	+1.3	+1.9	40 38 49.03	- 2 25.80	+ 4	+ 45	- 4	6	23.74	31.3
		2		18.1573	22.6370	+ 16	+1.8	+1.3	40 38 16.78	- 1 53.32	+ 3	+ 45	- 3	6	23.97	
		3		25.7033	28.7683	+196	+ .1	- .5	40 35 4.54	+ 1 18.00	- 2	- 5	+ 3	6	22.56	31.3
		5		19.9747	20.2627	+ 2	+2.0	+1.7	40 36 14.91	+ 7.30	- 0	+ 67	0	8	22.96	31.3
		6		7.2643 ⁱⁱ	29.5137 ^{iv}	- 31	- .4	.0	40 45 46.68	- 9 22.54	-1.01	- 6	-16	6	22.97	30.9
		7		25.5847	14.4873	+ 3	- .2	- .2	40 41 3.85	- 4 40.62	+ 7	- 5	- 8	6	23.23	30.5
		8		30.6460 ^{iv}	9.2120 ⁱⁱ	- 1	-1.6	- .5	40 27 20.33	+ 9 1.99	+1.02	- 32	+18	8	23.28	
		9		22.6443	18.6250	+ 22	+ .4	+ .7	40 34 41.71	+ 1 41.69	- 2	+ 15	+ 3	6	23.62	
Mar. 23	I	10		29.0357	12.5127	+109	+ .9	- .3	40 29 25.08	+ 6 58.09	- 10	+ 10	+12	6	23.35	30.8
		6	R	17.9890	24.6390	+ 78	+2.9	+2.1	40 33 34.04	+ 2 48.35	- 4	+ 73	+ 5	6	23.19	40.9
		7		13.6073	29.7520	+235	+1.5	+1.6	40 43 12.03	- 6 48.84	+ 10	+ 45	-13	7	23.68	39.9
		8		17.9277	24.3477	+ 65	+ .8	+1.5	40 33 40.96	+ 2 42.51	- 4	+ 32	+ 5	6	23.86	39.4
		9		18.6870	23 9640	+ 62	+1.4	+ .2	40 38 36.51	- 2 13.59	+ 3	+ 25	- 4	7	23.23	
Mar. 25	II	10		32.0287 ^{iv}	10.4970 ⁱⁱ	+ 16	- .2	- .1	40 27 17.32	+ 9 4.51	+1.07	- 4	+19	9	23.14	39.1
		1	D	17.3913	23.1977	+ 15	+1.6	+1.5	40 38 49.61	- 2 26.86	+ 4	+ 44	- 4	6	23.25	40.0
		2		21.9073	17.3787	- 14	+ .2	.0	40 38 17.35	- 1 54.48	+ 3	+ 3	- 3	6	22.96	
		3		21.0763	18.0010	- 13	.0	- .4	40 35 5.08	+ 1 17.73	- 2	- 5	+ 3	6	22.83	40.0
		4		20.4850	19.0217	- 2	- .2	+ .2	40 37 0.29	- 37.00	+ 1	0	- 1	7	23.36	39.6
		5		20.3453	20.0393	+ 2	+ .4	- .3	40 36 15.37	+ 7.74	- 0	+ 2	0	8	23.21	
		6		29.5543 ^{iv}	7.3140 ⁱⁱ	- 30	- .7	-1.9	40 45 47.17	- 9 22.31	-1.06	- 35	-16	6	23.35	39.4
		7		15.0333	26.1467	+ 56	-1.8	- .3	40 41 4.30	- 4 41.16	+ 7	- 33	- 8	6	22.86	
		8		8.2597 ⁱⁱ	29.6753 ^{iv}	- 12	.0	- .1	40 27 20.72	+ 9 1.50	+1.07	- 2	+18	8	23.53	39.1
		9		21.4143	25.4190	+120	- .2	- .4	40 34 42.11	+ 1 41.57	- 2	- 8	+ 3	6	23.67	
Mar. 28	II	10		12.4927	29.0053	-106	- .5	- .2	40 29 25.47	+ 6 57.28	- 10	- 10	+12	6	22.73	
		1	R	23.4780	17.6397	+ 29	+ .4	+ .1	40 38 50.27	- 2 27.70	+ 4	+ 8	- 4	6	22.71	31.5
		2		17.6227	22.1960	- 5	+ .9	+1.1	40 38 18.02	- 1 55.63	+ 3	+ 28	- 3	6	22.73	
		3		19.4963	22.5150	+ 26	+2.7	+1.3	40 35 5.72	+ 1 16.40	- 2	+ 60	+ 3	6	22.79	31.2
		4		19.6317	21.1740	+ 3	- .2	+1.1	40 37 0.88	- 39.01	+ 1	+ 11	- 1	7	22.05	
		5		22.5147	22.7637	+ 6	+ .3	+ .1	40 36 15.92	+ 6.31	- 0	+ 6	0	8	22.37	31.5
		6		9.5123 ⁱⁱ	31.8087 ^{iv}	+ 12	- .4	+1.6	40 45 47.77	- 9 23.83	-1.06	+ 14	-16	6	22.92	31.6
		7		26.2230	15.0723	+ 62	+1.1	+ .1	40 41 4.87	- 4 42.12	+ 7	+ 19	- 8	6	22.99	31.4
		8		32.2333 ^{iv}	10.8677 ⁱⁱ	+ 18	+ .3	+ .8	40 27 21.23	+ 9 0.31	+1.07	+ 15	+18	8	23.02	
		9		22.8273	18.8500	+ 30	+ .4	+ .2	40 34 42.65	+ 1 40.65	- 2	+ 9	+ 3	6	23.46	
Apl. 10	II	10		29.0003	12.5137	+106	-1.6	- .6	40 29 26.00	+ 6 57.16	- 10	- 33	+12	6	22.91	31.1
		1	D	18.3873	23.3290	+ 36	+ .9	+1.4	40 38 52.88	- 2 30.34	+ 6	+ 32	- 4	6	22.94	36.4
		2		21.2993	16.6307	- 46	+2.4	+2.5	40 38 20.65	+ 1 57.94	+ 5	+ 70	- 3	6	23.49	
		3		20.4983	17.5670	- 24	+2.0	+2.4	40 35 8.29	+ 1 14.06	- 3	+ 62	+ 3	6	23.03	35.8
		4		21.0473	19.4480	+ 2	- .6	+ .6	40 37 3.23	- 0 40.45	+ 2	- 2	- 1	7	22.84	
		5		20.3713	20.2027	+ 1	+2.2	+2.4	40 36 18.13	+ 4.27	- 0	+ 66	0	8	23.14	
		6		31.2073 ^{iv}	8.8193 ⁱⁱ	- 1	+2.7	+1.8	40 45 50.22	- 9 26.12	- 97	+ 66	-16	6	23.69	
		7		13.7890	25.0623	- 62	+2.0	+2.5	40 41 7.21	- 4 44.91	+ 12	+ 64	- 8	6	23.04	35.1
		8		8.3083 ⁱⁱ	29.5890 ^{iv}	- 11	+1.9	+2.8	40 27 23.33	+ 8 58.09	+ 98	+ 66	+18	8	23.32	35.6
		9		14.4460	18.3273	-122	+2.1	+1.7	40 34 44.85	+ 1 37.84	- 4	+ 55	+ 3	6	23.29	
Apl. 11	II	10		12.1687	28.5800	+ 54	+ .4	-1.4	40 29 28.21	+ 6 55.12	- 17	- 11	+12	6	23.23	35.5
		1	R	24.9387	19.0023	+103	+ .2	+1.8	40 38 53.12	- 2 30.37	+ 6	+ 26	- 4	6	23.09	35.9
		2		17.1537	21.7933	- 22	.0	- .5	40 38 20.89	- 1 57.26	+ 5	- 6	- 3	6	23.65	
		3		18.7727	21.7333	+ 7	- .9	- .7	40 35 8.53	+ 1 14.88	- 3	- 23	+ 3	6	23.24	35.0
		4		20.7417	22.3590	+ 23	+ .3	.0	40 37 3.46	- 40.95	+ 2	+ 5	- 1	7	22.64	

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther- mom.
						A	B		Micrometer.	δ	l	r	Mer		
Apl. 11	II	5 R	21.5950	21.7847	+ 4	-1.7	-1.5	$\begin{smallmatrix} 0 & 36 & 18.34 \\ 40 & 36 & 18.34 \end{smallmatrix}$	+ 4.81	- 0	- 46	0	8	$\begin{smallmatrix} 40 & 36 & 22.77 \\ 40 & 36 & 22.77 \end{smallmatrix}$	0
		6	9.5497 ^{II}	31.9193 ^{IV}	+ 14	-1.9	-1.3	40 45 50.45	- 9 25.69	- 97	- 47	-16	6	23.22	35.0
		7	26.9000	15.6823	+126	- .4	- .8	40 41 7.45	- 4 43.98	+ 12	- 16	- 8	6	23.41	
		8	32.5597 ^{IV}	11.2733 ^{II}	+ 23	-1.0	- .2	40 27 23.54	+ 8 58.32	+ 98	- 18	+18	8	23.92	
		9	22.6130	18.7257	+ 23	- .8	.0	40 34 45.07	+ 1 38.36	- 4	- 13	+ 3	6	23.35	
Apl. 14	II	10	30.6600	14.3023	+354	+ .5	+ .6	40 29 28.42	+ 6 54.53	- 17	+ 15	+12	6	23.11	35.0
		1 D	17.9547	23.8813	+ 49	-1.2	- .6	40 38 53.77	- 2 29.99	+ 6	- 27	- 4	6	23.59	43.5
		2	22.7533	18.0990	+ 17	-1.6	-2.2	40 38 21.56	- 1 57.74	+ 5	- 53	- 3	6	23.37	42.7
		3	18.6480	15.6957	- 73	-2.4	-1.1	40 35 9.20	+ 1 14.47	- 3	- 52	+ 3	6	23.21	42.6
		4	22.4910	20.8690	+ 24	+ .7	+ .8	40 37 4.08	- 41.08	+ 2	+ 21	- 1	7	23.29	
		5	20.9853	20.8250	+ 1	- .9	- .2	40 36 18.94	+ 4.06	- 0	- 17	0	8	22.91	
		6	31.1033 ^{IV}	8.7117 ^{II}	- 4	- .7	- .7	40 45 51.12	- 9 26.20	- 97	- 20	-16	6	23.65	
		7	15.3093	26.5577	+ 91	- .6	.0	41 41 8.11	+ 4 44.67	+ 12	- 9	- 8	6	23.45	
		8	8.5440 ^{II}	29.8497 ^{IV}	- 9	-2.2	- .5	40 27 24.14	+ 8 58.73	+ 98	- 42	+18	8	23.69	
		9	16.9377	20.8213	- 40	+1.5	- .2	40 34 45.72	+ 1 38.10	- 4	+ 21	+ 3	6	24.08	
Apl. 15	II	10	11.9623	28.3213	+ 20	+1.3	- .3	40 29 29.09	+ 6 53.72	- 17	+ 17	+12	6	22.99	42.6
		1 R	24.5263	18.5713	+ 81	+ .4	+ .9	40 38 53.97	- 2 30.79	+ 6	+ 21	- 4	6	23.47	43.1
		2	17.1363	21.8333	- 22	+ .5	+ .8	40 38 21.75	- 1 58.84	+ 5	+ 18	- 3	6	23.17	42.6
		3	19.1570	22.0747	+ 16	+2.0	+ .2	40 35 9.40	+ 1 13.82	- 3	+ 34	+ 3	6	23.62	
		18 II	17.4787	23.4730	+ 27	+ .6	+1.0	40 38 54.59	- 2 31.64	+ 6	+ 22	- 4	6	23.25	
		2	23.2750	18.5763	+ 39	.0	- .2	40 38 22.40	- 1 58.91	+ 5	- 2	- 3	6	23.55	44.3
		3	22.1453	19.2530	+ 17	+1.2	+ .3	40 35 10.04	+ 1 13.18	- 3	+ 23	+ 3	6	23.51	44.6
		4	20.7513	22.4147	+ 23	-2.0	- .6	40 37 4.83	- 42.12	+ 2	- 39	- 1	7	22.40	
		5	20.8557	21.0330	+ 1	-2.4	-2.3	40 36 19.66	+ 4.49	- 0	- 68	0	8	23.55	
		6	8.2493 ^{II}	30.6890 ^{IV}	- 11	- .2	+2.5	40 45 51.93	- 9 27.40	- 97	+ 29	-16	6	23.75	
Apl. 19		7	26.2590	14.9513	+ 60	+ .9	+ .8	40 41 8.91	- 4 46.09	+ 12	+ 24	- 8	6	23.16	42.9
		8	33.6620 ^{IV}	12.4170 ^{II}	+ 34	+1.1	- .7	40 27 24.85	+ 8 57.30	+ 98	+ 8	+18	8	23.47	54.4c
		9	22.4220	18.5810	+ 17	-1.9	- .6	40 34 46.48	+ 1 37.17	- 4	- 38	+ 3	6	23.32	
		10	29.2090	12.8933	+149	-1.0	- .9	40 29 29.87	+ 6 52.95	- 17	- 27	+12	6	22.56	
		19 II	22.9717	16.9717	- 2	+ .8	+ .3	40 38 54.83	- 2 31.72	+ 6	+ 17	- 4	6	23.36	
		2	18.0680	22.8080	+ 19	- .2	+ .9	40 38 22.63	- 1 59.91	+ 5	+ 8	- 3	6	22.88	53.4
		3	18.5833	21.4753	0	+ .4	+3.1	40 35 10.27	+ 1 13.13	- 3	+ 46	+ 3	6	22.92	
		4	20.9577	19.2967	+ 1	- .6	+ .6	40 37 5.06	- 42.00	+ 2	- 2	- 1	7	23.12	
		5	20.3087	20.1617	- 0	- .8	- .7	40 36 19.87	+ 3.72	- 0	- 22	0	8	23.45	
		6	30.3723 ^{IV}	7.9133 ^{II}	- 17	+ .3	- .3	40 45 52.16	- 9 27.87	- 97	+ 1	-16	6	23.23	
Apl. 20		7	15.1640	26.4753	+ 81	- .2	.0	40 41 9.13	- 4 46.23	+ 12	- 3	- 8	6	22.97	53.3
		8	8.1767 ^{II}	29.4340 ^{IV}	- 12	- .7	.0	40 27 25.05	+ 8 57.50	+ 98	- 11	+18	8	23.68	53.0
		9 D	17.0670	20.9057	- 33	+ .1	- .6	40 34 46.69	+ 1 36.98	- 4	- 6	+ 3	6	23.66	45.2
		10	12.3223	28.6427	+ 68	+1.0	- .2	40 29 30.08	+ 6 52.86	- 17	+ 13	+12	6	23.08	
		19 II	16.7740	22.7653	- 13	-2.0	-1.9	40 38 55.08	- 2 31.47	+ 6	- 56	- 4	6	23.13	
		2 D	22.5360	17.8183	+ 8	-2.0	-2.5	40 38 22.89	- 1 59.32	+ 5	- 64	- 3	6	23.01	46.2
		3 D	21.3860	18.4987	- 2	- .2	- .3	40 35 10.52	+ 1 13.01	- 3	- 7	+ 3	6	23.52	
		4 R	19.6467	21.3227	+ 5	- .2	+ .2	40 37 5.29	- 42.39	+ 2	- 0	- 1	7	22.98	
		5	21.4690	21.6057	+ 1	- .4	- .8	40 36 20.09	+ 3.46	- 0	- 16	0	8	23.47	
		6	8.5290 ^{II}	30.9840 ^{IV}	- 6	-1.9	.0	40 45 52.41	- 9 27.80	- 97	- 30	-16	6	23.24	
Apl. 21		7	25.8120	14.4667	+ 12	+ .3	.0	40 41 9.38	- 4 46.92	+ 12	+ 5	- 8	6	22.61	44.4
		8	32.5640 ^{IV}	11.3090 ^{II}	+ 23	-1.1	- .7	40 27 25.27	+ 8 57.53	+ 98	- 26	+18	8	23.78	45.4
		9	24.5520	20.7273	+ 89	-1.6	- .9	40 34 46.92	+ 1 36.94	- 4	- 37	+ 3	6	23.54	47.3
		10	28.4423	12.1330	+ 41	+ 3	- .4	40 29 30.32	+ 6 52.51	- 17	0	+12	6	22.84	
		19 II	23.8867	17.8707	+ 47	- .6	+ .2	40 38 55.35	- 2 32.24	+ 6	- 7	- 4	6	23.12	
		2 R	18.1757	22.8960	+ 22	-1.7	- .9	40 38 23.16	- 1 59.42	+ 5	- 39	- 3	6	23.43	47.8
		3 R	19.0743	21.9520	+ 13	-1.0	- .8	40 35 10.79	+ 1 12.80	- 3	- 26	+ 3	6	23.39	
		4 D	21.7153	20.0293	+ 12	- .3	+ .4	40 37 5.54	- 42.66	+ 2	+ 2	- 1	7	22.98	
		5	24.5763	24.4523	+ 4	-1.2	-1.4	40 36 20.34	+ 3.15	- 0	- 37	0	8	23.20	
		6	31.0857 ^{IV}	8.6297 ^{II}	- 5	+ .4	- .2	40 45 52.68	- 9 27.83	- 97	+ 4	-16	6	23.82	

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
Apl. 21	II 7	D	13.8827	26.2357	-43	-2.3	-1.2	40 41 9.63	-4 46.97	+12	-52	-8	6	40 36 22.24	47.4
			9.2260 ⁱⁱ	30.4457 ^{iv}	-1	+ .4	+ .1	40 27 25.51	+ 8 56.57	+98	+ 8	+18	8	23.40	
			18.1303	21.9447	+1	-1.0	-.9	40 34 47.18	+1 36.46	-4	-27	+3	6	23.42	46.6
Apl. 23	II 1	D	12.5253	28.8113	+93	+1.1	+ .4	40 29 30.57	+ 6 52.06	-17	+22	+12	6	22.86	
			17.1100	23.1430	+6	-1.0	-1.2	40 38 55.90	-2 32.57	+6	-31	-4	6	23.10	47.3
May 1	II 1	R	21.8953	17.1347	-21	-.2	-1.4	40 38 23.73	-2 0.33	+5	-21	-5	6	23.25	
			22.5500	19.7070	+28	+ .2	-.2	40 35 11.36	+1 11.96	-3	0	+2	6	23.37	46.1
			18.3003	20.0163	-13	-2.0	-.1	40 37 6.08	-43.36	+2	-33	-2	7	22.46	
			21.3387	21.4420	+2	-1.2	-1.9	40 36 20.85	+2.62	-0	-44	0	8	23.11	45.4
			9.1953 ⁱⁱ	31.6677 ^{iv}	+9	+ .4	-.8	40 45 53.24	-9 28.28	-1.05	-3	-17	6	23.77	
			25.5317	14.1977	-13	-.8	-.8	40 41 10.18	-4 46.57	+12	-23	-9	6	23.47	45.7
			31.4723 ^{iv}	10.2647 ⁱⁱ	+8	-.1	+ .6	40 27 26.02	+ 8 56.29	+1.06	+6	+18	8	23.69	
			23.5970	20.7940	+55	-.1	-.2	40 34 47.72	+1 36.30	-4	-4	+3	6	24.03	
			27.4743	11.1867	-95	-.3	0	40 29 31.13	+ 6 51.62	-17	-5	+12	6	22.71	45.6
			23.7223	17.5903	+36	+2.7	+2.5	40 38 57.69	-2 35.15	+6	+75	-4	6	23.37	
May 3	II 1	R	17.9663	22.8263	+18	-1.0	-.2	40 38 25.57	-2 2.94	+5	-18	-3	6	22.53	
			17.7720	20.5350	-19	-1.1	-1.0	40 35 13.25	+1 9.82	-3	-30	+3	6	22.83	47.4
			21.9757	20.1610	+17	+1.2	+ .7	40 37 7.85	+45.93	+2	+28	-2	7	22.27	47.5
			21.7280	21.7187	0	+1.4	-.3	40 36 22.56	+0.24	-0	+18	0	8	23.06	
			32.1960 ^{iv}	9.6530 ⁱⁱ	+19	-.4	-1.5	40 45 55.17	-9 30.09	-1.05	-25	-17	6	23.67	47.2
			15.8513	27.2973	+157	+2.7	+1.7	40 41 12.13	-4 49.83	+12	+65	-9	6	23.04	46.1
			9.7507 ⁱⁱ	30.8627 ^{iv}	+2	+ .7	+ .5	40 27 27.80	+ 8 53.86	+1.06	+17	+18	8	23.15	
			19.8513	23.5603	+58	-.4	-.8	40 34 49.63	+1 33.94	-4	-17	+3	6	23.45	
			13.1827	29.3587	+180	+1.2	-.3	40 29 33.10	+ 6 49.49	-17	+16	+12	6	22.76	
			18.0827	24.2100	+62	+1.7	+ .4	40 38 58.16	-2 35.10	+6	+32	-4	6	23.46	
May 6	II 1	R	23.2250	18.3437	+33	+1.1	+1.2	40 38 26.04	-2 3.52	+5	+33	-3	6	22.93	
			21.9130	19.1710	+13	-1.1	-.9	40 35 13.72	+1 9.37	-3	-28	+2	6	22.86	62.6
			18.4170	20.2183	-11	+1.7	+ .5	40 37 8.29	+45.52	+2	+34	-2	7	23.18	
			22.4593	22.4613	0	+ .2	-.3	40 36 22.98	+ .05	-0	0	0	8	23.11	
			8.5070 ⁱⁱ	31.0853 ^{iv}	-6	-.9	-1.3	40 45 55.64	-9 30.92	-1.05	-31	-17	6	23.25	
			28.1683	16.7253	+241	+ .5	-1.6	40 41 12.61	-4 49.97	+12	-12	-9	6	22.61	62.0
			32.6077 ^{iv}	11.5147 ⁱⁱ	+21	+ .9	+1.5	40 27 28.23	+ 8 53.43	+1.06	+33	+18	8	23.31	
			24.8893	21.2267	+100	+1.0	+1.3	40 34 50.10	+1 32.87	-4	+32	+3	6	23.34	d
			24.3623	18.2123	+70	+1.4	+ .7	40 38 58.95	-2 35.69	+6	+31	-4	6	23.65	65.6
			18.2103	23.0987	+28	-.1	-1.3	40 38 26.85	-2 3.68	+5	-18	-3	6	23.07	
May 9	II 1	R	19.2073	21.9197	+13	+ .2	-.1	40 35 14.55	+1 8.62	-3	+1	+3	6	23.24	65.6
			22.5233	20.6877	+25	0	+ .4	40 37 9.06	-46.48	+2	+5	-2	7	22.70	
			20.4747	20.6027	0	-1.4	-1.4	40 36 23.73	-0.71	0	-40	0	8	22.70	
			31.8683 ^{iv}	9.2487 ⁱⁱ	+13	+1.3	+ .3	40 45 56.48	-9 32.01	-1.05	+25	-17	6	23.56	
			14.6423	26.1460	+39	-1.0	-.1	40 41 13.44	-4 50.99	+12	-17	-9	6	22.37	64.8
			11.5660 ⁱⁱ	32.6453 ^{iv}	+21	+ .1	+ .9	40 27 28.99	+ 8 53.08	+1.06	+13	+18	8	23.52	
			17.3793	21.0390	-26	+ .4	+ .9	40 34 50.93	+1 32.48	-4	+18	+3	6	23.64	
			13.4987	29.6330	+220	+ .9	0	40 29 34.41	+ 6 48.54	-17	+14	+12	6	23.10	63.5
			17.8607	24.0670	+53	+ .4	+ .1	40 38 59.73	-2 37.07	+9	+8	-4	6	22.85	70.0
			24.6453	19.7220	+94	+ .9	+ .3	40 38 27.66	-2 4.73	+7	+18	-3	6	23.21	
May 9	II 2	D	22.1153	19.4380	+17	-.8	-.3	40 35 15.38	+1 7.74	-3	-17	+3	6	23.01	69.9
			18.2320	20.0937	-14	-1.7	-1.4	40 37 9.85	-47.04	+3	-45	-2	7	22.44	
			21.5647	21.4967	+1	-.9	-.9	40 36 24.51	-1.72	-0	-26	0	8	22.61	
			9.0933 ⁱⁱ	31.7577 ^{iv}	+9	+1	-.1	40 45 57.34	-9 33.13	-97	0	-17	6	23.13	
			26.3013	14.7713	+55	-.4	-.7	40 41 14.33	-4 51.69	+16	-15	-9	6	22.62	68.6
			31.7463 ^{iv}	10.6903 ⁱⁱ	+10	0	-.5	40 27 29.81	+ 8 52.46	+1.00	-6	+18	8	23.47	
			21.8370	18.1977	0	-1.6	-.5	40 34 51.80	+1 32.03	-5	-32	+3	6	23.55	
			23.6897	12.5827	+91	+1.1	+1	40 29 35.32	+ 6 47.52	-21	+19	+12	6	23.00	68.4
			29.8550 ^{iv}	14.2747 ⁱⁱ	-82	-.9	-.3	40 42 58.10	-6 33.77	-1.07	-18	-14	9	23.03	67.6
			6.8433 ⁱⁱ	31.0547 ^{iv}	-41	+1.1	+1.1	40 46 36.44	-10 12.12	-95	+31	-24	11	23.55	

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther- mom.
						A	B		Micrometer.	δ	i	r	Mer		
May 9	III 3	R	8.8813 ⁱⁱ	34.2007 ^{iv}	+ 73	+2.1	+1.7	40 25 40.63	+10 40.44	+ 94	+ 55	+18	5	40 36 23.79	66.4
			9.4077 ⁱⁱ	34.4990 ^{iv}	+ 88	+1.8	+ .9	40 25 47.13	+10 34.70	+ 95	+ 40	+19	6	23.43	65.4
			26.6343	14.9430	+ 82	+ .2	+ .3	40 31 26.78	+ 4 55.84	- 15	+ 6	+10	7	23.70	
			18.3283	21.8740	+ 2	+3.0	+2.7	40 37 51.90	- 1 29.66	+ 5	+ 82	- 3	6	23.14	
			18.1500	16.6290	- 36	+ .1	-1.1	40 37 1.17	- 38.37	+ 2	- 12	- 1	6	23.75	
May 10	III 1	D	15.2193	21.9240	- 85	+ .3	+ .5	40 33 33.17	+ 2 49.33	- 9	+ 11	+ 4	6	22.62	65.5
			12.4907	26.2783	- 73	-1.2	- .1	40 42 11.31	- 5 48.46	+ 19	- 21	-10	5	23.78	
			10.5550	26.2287	-220	+1.2	+1.2	40 42 58.36	- 6 35.78	+ 21	+ 35	-14	9	23.09	70.4
			34.2160 ^{iv}	10.0163 ⁱⁱ	+ 78	- .3	- .7	40 46 36.69	-10 12.13	- 95	- 14	-24	11	23.34	69.9
			31.4463 ^{iv}	6.1153 ⁱⁱ	- 59	- .7	-1.0	40 25 41.32	+10 40.39	+ 94	- 24	+18	5	23.64	
			32.8750 ^{iv}	7.7513 ⁱⁱ	+ 15	-1.5	- .8	40 25 47.40	+10 35.33	+ 95	- 34	+19	6	23.59	
			15.0630	26.7647	+ 93	- .8	- .2	40 31 27.04	+ 4 56.13	- 15	- 15	+10	7	23.04	68.9
			22.9010	19.3640	+ 35	- .2	- .1	40 37 52.16	- 1 29.53	+ 5	- 4	- 3	6	22.67	68.6
May 12 May 13	II 1	D	21.5390	21.0753	+ 2	+ .2	- .2	40 37 1.43	- 38.85	+ 2	0	- 1	6	22.65	68.7
			24.0813	17.4020	+ 44	+ .3	- .2	40 33 33.43	+ 2 49.01	- 9	+ 2	+ 4	6	22.47	68.3
			29.8930	16.1550	+360	+ .3	- .3	40 42 11.56	- 5 48.30	+ 19	+ 1	-10	5	23.41	
			23.8617	17.6380	+ 41	- .7	- .3	40 39 0.37	- 2 37.48	+ 9	- 14	- 4	6	22.86	45.5
			17.0733	22.0533	- 20	+1.5	+1.2	40 38 28.34	- 2 5.88	+ 7	+ 39	- 3	6	22.95	44.7
			18.2217	24.4367	+ 74	- .8	- .8	40 39 0.58	- 2 37.34	+ 9	- 23	- 4	6	23.12	49.2
			22.7573	17.7883	+ 12	+2.3	+ .3	40 38 27.66	- 2 5.68	+ 7	+ 40	- 3	6	22.48	
			21.2760	18.6367	- 3	- .8	- .4	40 35 16.30	+ 1 6.73	- 3	- 18	+ 3	6	22.91	48.6
May 16	II 1	R	21.1457	19.2220	+ 1	+1.0	+1.4	40 37 10.72	- 48.65	+ 3	+ 34	- 2	7	22.49	
			20.3793	20.4773	0	0	+1.4	40 36 25.36	- 2.48	+ 0	+ 18	0	8	23.14	
			31.6107 ^{iv}	8.9127 ⁱⁱ	+ 5	+1.7	+ .8	40 45 58.32	- 9 33.97	- 97	+ 37	-17	6	23.64	
			15.7333	27.2700	+150	-1.0	+ .2	40 41 15.33	- 4 52.10	+ 16	- 13	- 9	6	23.23	47.0
			9.4760 ⁱⁱ	30.4667 ^{iv}	- 0	+ .9	+1.4	40 27 30.74	+ 8 50.79	+1.00	+ 32	+18	8	23.11	
			18.6693	22.2270	+ 13	+1.4	+1.7	40 34 52.82	+ 1 30.00	- 5	+ 44	+ 3	6	23.30	46.1
			24.0850	17.8487	+ 53	+1.3	+1.1	40 39 1.23	- 2 37.83	+ 9	+ 35	- 4	6	23.86	46.9
			18.6013	21.7490	+ 8	+1.4	+2.2	40 38 29.22	- 2 7.66	+ 7	+ 50	- 3	6	22.16	
May 18	III 1	R	19.3680	21.9870	+ 15	+ .5	- .4	40 35 16.99	+ 1 6.26	- 3	+ 3	+ 3	6	23.34	
			19.4157	21.3477	+ 5	-1.5	0	40 37 11.36	- 0 48.87	+ 3	- 24	- 2	7	22.33	46.6
			21.2933	21.2007	0	-3.7	-3.7	40 36 25.98	- 2.34	- 0	-1.02	- 0	8	22.70	
			8.9763 ⁱⁱ	31.7003 ^{iv}	+ 8	+ .2	+ .3	40 45 59.04	- 9 34.64	- 97	+ 6	-17	6	23.38	
			27.4067	15.8260	+162	- .1	0	40 41 16.05	- 4 53.25	+ 16	- 1	- 9	6	22.92	45.8
			30.2430 ^{iv}	9.2462 ⁱⁱ	- 2	- .2	- .6	40 27 31.40	+ 8 50.94	+1.00	- 10	+18	8	23.50	
			23.7667	20.2223	+ 62	- .5	- .2	40 34 53.55	+ 1 29.78	- 5	- 10	+ 3	6	23.27	
			29.4787	13.4423	+203	-1.9	-1.6	40 29 37.12	+ 6 46.02	- 21	- 51	+12	6	22.60	44.8
May 18	III 1	R	30.2933	14.6540	+338	-1.2	- .6	40 42 59.69	- 6 36.32	+ 21	- 27	-14	9	23.26	41.3
			11.0693 ⁱⁱ	35.3107 ^{iv}	+119	+ .4	- .3	40 46 37.97	-10 13.29	- 95	+ 2	-24	11	23.62	
			8.3527 ⁱⁱ	33.6310 ^{iv}	+ 45	+ .7	- .2	40 25 42.79	+10 39.32	+ 94	+ 8	+18	5	23.36	
			27.2093	15.5683	+136	+ .7	- .4	40 31 28.37	+ 4 54.71	- 15	+ 6	+10	7	23.16	40.0
			19.3260	22.8913	+ 34	-2.3	-1.4	40 37 53.53	- 1 30.24	+ 5	- 55	- 3	6	22.82	d
			21.2880	19.6697	+ 4	+ .7	- .2	40 37 2.77	- 40.93	+ 2	+ 8	- 1	6	21.99	
			17.2320	23.8687	+ 32	- .4	- .5	40 33 34.74	+ 2 47.90	- 9	- 13	+ 4	6	22.52	
			14.0570	27.8740	+116	-1.4	+ .9	40 42 12.82	- 5 49.68	+ 19	- 11	-10	5	23.17	39.9
May 18	II 1	D	18.2890	24.5590	+ 79	- .3	0	40 39 1.73	- 2 38.75	+ 9	- 5	- 4	6	23.04	52.0
			21.8227	16.8053	- 32	+1.9	- 0	40 38 29.73	- 2 6.79	+ 7	+ 30	- 3	6	23.34	
			21.1150	18.5097	- 6	-1.3	- .8	40 35 17.53	+ 1 5.86	+ 3	- 31	+ 3	6	23.14	
			21.6063	19.6777	+ 9	- .9	-1.5	40 37 11.86	- 48.79	+ 3	- 33	- 2	7	22.82	
			19.6657	19.8327	0	+2.1	+1.0	40 36 26.48	- 4.22	- 0	+ 46	- 0	8	22.80	
			31.5723 ^{iv}	8.8167 ⁱⁱ	+ 11	+1.6	+ .3	40 45 59.58	- 9 35.44	- 97	+ 29	-17	6	23.35	52.4
			14.5333	26.1503	+ 32	-2.2	- .2	40 41 16.61	- 4 53.84	+ 16	- 38	- 9	6	22.52	51.6
			9.5340 ⁱⁱ	30.5093 ^{iv}	0	- .2	0	40 27 31.91	+ 8 50.40	+1.00	- 3	+18	8	23.54	
May 18	II 1	D	17.6677	21.2073	- 19	- .2	- .1	40 34 54.10	+ 1 29.46	- 5	- 5	+ 3	6	23.55	51.1
			13.1960	29.1993	+167	- .1	+ .9	40 29 37.68	+ 6 45.09	- 21	+ 10	+12	6	22.84	50.7

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
May 18	III 1	D	12.2160	27.9227	+ 7	-.7	-2.0	40 43 0.16	- 6 37.19	+ 21	- 36	-14	9	40 36 22.77	48.6
			33.4257 ^{iv}	9.1643 ⁱⁱ	+ 49	-.1	+ .9	40 46 38.40	-10 13.62	- 95	+ 10	-24	11	23.80	
			31.6787 ^{iv}	6.4143 ⁱⁱ	- 47	-.3	-1.0	40 25 43.30	+10 38.74	+ 94	- 18	+18	5	23.03	
			32.9903 ^{iv}	7.9407 ⁱⁱ	+ 21	-1.8	-1.6	40 25 49.32	+10 33.48	+ 95	- 49	+19	6	23.51	
			13.7330	25.3873	- 44	-.5	-.3	40 31 28.83	+ 4 54.59	- 15	- 12	+10	7	23.32	48.4
May 22	II 1	R	21.5687	17.9733	- 7	-.3	-.8	40 37 53.99	- 1 30.90	+ 5	- 15	- 3	6	23.02	
			23.2150	16.8917	+ 2	+ .9	+ .2	40 39 2.74	- 2 39.90	+ 9	+ 17	- 4	6	23.12	49.6
			17.1100	23.1577	+ 7	-1.2	-1.1	40 38 30.78	- 2 7.66	+ 7	- 33	- 3	6	22.89	
			17.7933	20.3290	- 18	+1.9	+1.9	40 35 17.53	+ 1 4.07	- 3	+ 55	+ 3	6	22.21	49.8
			19.2163	21.2077	- 2	-1.0	-.2	40 37 12.90	- 50.35	+ 3	- 18	- 2	7	22.45	
			20.9503	20.7730	+ 1	-1.1	-.8	40 36 27.50	- 4.49	- 0	- 27	0	8	22.82	
			8.4027 ⁱⁱ	31.2087 ^{iv}	- 7	-.7	-1.2	40 46 0.74	- 9 36.67	- 97	- 27	-17	6	22.72	49.9
			26.0510	14.3677	+ 20	+1.6	+1.7	40 41 17.79	- 4 55.48	+ 16	+ 48	- 9	6	22.92	
			31.6563 ^{iv}	10.7547 ⁱⁱ	+ 8	-.6	+ .1	40 27 33.01	+ 8 48.55	+1.00	- 8	+18	8	22.74	49.9
			23.3850	19.9000	+ 52	-.6	-.3	40 34 55.29	+ 1 28.26	- 5	- 13	+ 3	6	23.46	
	III 1	R	28.1230	12.1563	+ 18	-.4	-.7	40 29 38.91	+ 6 43.79	- 21	- 11	+12	6	22.56	49.9
			31.3573	15.6577	+478	+ .2	-.2	40 43 1.28	- 6 38.20	+ 21	0	-14	9	23.24	47.4
			9.6063 ⁱⁱ	33.9210 ^{iv}	+ 65	-.2	-.1	40 46 39.49	-10 15.00	- 95	- 4	-24	11	23.37	47.2
			8.4193 ⁱⁱ	33.5987 ^{iv}	+ 46	+3.3	+1.6	40 25 44.51	+10 36.82	+ 94	+ 73	+18	5	23.23	
			8.6187 ⁱⁱ	33.6077 ^{iv}	+ 49	+ .7	0	40 25 50.51	+10 32.01	+ 95	+ 11	+19	6	23.83	
			25.4130	13.8250	- 39	+ .9	+ .3	40 31 29.94	+ 4 52.92	- 15	+ 18	+10	7	23.06	47.2
			18.6003	22.2450	+ 13	-1.4	-.3	40 37 55.13	- 1 32.20	+ 5	- 26	- 3	6	22.75	
			20.2147	18.5660	- 8	-.2	-.5	40 37 4.33	- 41.67	+ 2	- 9	- 1	6	22.64	
			18.3367	24.9090	+ 92	+ .9	-.2	40 33 36.77	+ 2 46.42	- 9	+ 12	+ 4	6	23.32	46.6
			13.4037	27.2883	+ 42	-1.9	+ .2	40 42 14.29	- 5 51.20	+ 19	- 28	-10	5	22.95	46.6
May 23	II 1	D	16.5467	22.8897	- 16	-1.2	-.2	40 39 2.96	- 2 40.35	+ 9	- 22	- 4	6	22.50	61.6
			22.9833	17.9160	+ 20	+ .9	+1.8	40 38 31.02	- 2 8.19	+ 7	+ 37	- 3	6	23.30	
			22.4753	19.9267	+ 28	-1.4	-.9	40 35 18.87	+ 1 4.52	- 3	- 34	+ 3	6	23.11	60.1
			21.5437	19.5367	+ 7	-.1	+1.6	40 37 13.14	- 50.77	+ 3	+ 19	- 2	7	22.64	
			19.4723	19.6840	- 1	+ .5	-1.2	40 36 27.75	- 5.35	- 0	- 7	0	8	22.41	
			32.0083 ^{iv}	9.1977 ⁱⁱ	+ 14	+ .2	-.6	40 46 1.00	- 9 36.84	- 97	- 4	-17	6	23.04	
			14.7007	26.3997	+ 57	+ .4	+1.4	40 41 18.07	- 4 55.97	+ 16	+ 24	- 9	6	22.47	58.6
			9.2497 ⁱⁱ	30.1407 ^{iv}	- 3	+ .8	+1.9	40 27 33.27	+ 8 48.26	+1.00	+ 37	+18	8	23.16	
			18.2990	21.7450	- 0	+ .6	+ .8	40 34 55.57	+ 1 27.14	- 5	+ 19	+ 3	6	22.94	
			12.2617	28.2170	+ 31	+ .1	0	40 29 39.21	+ 6 43.54	- 21	+ 1	+12	6	22.73	58.4
	III 1	D	12.3080	28.0753	+ 25	-.2	+ .4	40 43 1.57	- 6 38.77	+ 21	+ 2	-14	9	22.98	55.6
			33.5757 ^{iv}	9.2460 ⁱⁱ	+ 55	+ .9	-.1	40 46 39.78	-10 15.36	- 95	+ 13	-24	11	23.47	56.3
			32.3437 ^{iv}	7.1487 ⁱⁱ	- 12	-2.5	-.9	40 25 44.84	+10 37.07	+ 94	- 51	+18	5	22.57	56.3
			32.9980 ^{iv}	8.0103 ⁱⁱ	+ 22	-1.9	-1.9	40 25 50.83	+10 31.91	+ 95	- 55	+19	6	23.39	55.6
			13.1740	24.7773	-103	-.6	-1.7	40 31 30.25	+ 4 53.15	- 15	- 32	+10	7	23.10	
			22.4090	18.7537	+ 19	+ .7	+ .1	40 37 55.44	- 1 32.48	+ 5	+ 12	- 3	6	23.16	
			19.4870	21.1140	+ 2	-1.2	-1.2	40 37 4.64	- 41.15	+ 2	- 35	- 1	6	23.21	
			23.8427	17.2587	+ 32	-.5	-.9	40 33 37.07	+ 2 46.57	- 9	- 19	+ 4	6	23.46	
			27.5213	13.6410	+ 69	-1.6	-.2	40 42 14.59	- 5 51.16	+ 19	- 28	-10	5	23.29	54.4
			25.4357	19.0917	+124	-1.1	-1.0	40 39 3.88	- 2 40.73	+ 9	- 30	- 4	6	22.96	61.8
May 28	II 1	R	17.5180	22.6170	+ 2	+ .3	+ .6	40 38 31.99	- 2 8.94	+ 7	+ 12	- 3	6	23.27	
			19.4987	21.9843	+ 15	+1.6	+2.1	40 35 19.91	+ 1 2.89	- 3	+ 52	+ 3	6	23.38	61.1
			20.9440	22.9743	+ 41	+1.0	+4.0	40 37 14.12	- 51.43	+ 3	+ 21	- 2	7	22.98	60.6
			21.8063	21.5793	+ 4	-.7	-1.7	40 36 28.71	- 5.75	- 0	- 33	- 0	8	22.71	
			9.0747 ⁱⁱ	31.9210 ^{iv}	+ 12	+ .1	+ .3	40 46 2.14	- 9 37.74	- 97	+ 5	-17	6	23.37	60.4
			26.3330	14.6303	+ 47	-.0	-.4	40 41 19.26	- 4 56.04	+ 16	- 5	- 9	6	23.30	60.0
			31.1387 ^{iv}	10.2653 ⁱⁱ	+ 3	-.1	-.1	40 27 34.37	+ 8 47.83	+1.00	- 3	+18	8	23.43	
			22.6723	19.2440	+ 28	+ .7	+1.8	40 34 56.81	+ 1 26.76	- 5	+ 34	+ 3	6	23.95	
			30.3203	14.4373	+329	-.1	+ .2	40 29 40.48	+ 6 42.46	- 21	+ 1	+12	6	22.92	59.0
			28.7387	12.9400	+117	-.4	+ .4	40 43 2.83	- 6 39.79	+ 21	- 1	-14	9	23.19	57.4

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther- mom.
						A	B		Micrometer.	δ	l	r	Mer		
May 28	III 2	R	7.9107 ⁱⁱ	32.2887 ^{iv}	+ 4	.0	-.7	40 46 41.02	-10 16.45	- 95	- 9	-24	11	40 36 23.40	0
			7.1950 ⁱⁱ	32.3230 ^{iv}	- 12	+1.5	+ .4	40 25 46.27	+10 35.38	+ 94	+ 29	+18	5	23.11	
			6.4070 ⁱⁱ	31.3303 ^{iv}	- 51	-.2	-.2	40 25 52.24	+10 30.10	+ 95	- 5	+19	6	23.49	
			27.2697	15.7700	+151	-.6	.0	40 31 31.59	+ 4 51.17	- 15	- 9	+10	7	22.69	57.3
			19.1537	22.8610	+ 33	-1.5	.0	40 37 56.85	- 1 33.83	+ 5	- 24	- 3	6	22.86	
			21.9400	20.2223	+ 15	+ .3	-.5	40 37 6.04	- 43.47	+ 2	- 1	- 1	6	22.63	55.8
			18.4503	24.9193	+ 95	-.4	+ .4	40 33 38.47	+ 2 43.82	- 9	- 1	+ 4	6	22.29	
			15.2607	29.2067	+270	+1.2	+ .8	40 42 15.95	- 5 53.33	+ 19	+ 29	-10	5	23.05	55.8
			15.3467	21.7423	- 82	-.1	+ .4	40 39 4.05	- 2 41.52	+ 9	+ 3	- 4	6	22.67	70.9
			23.5237	18.4167	+ 43	+ .4	+ .8	40 38 32.18	- 2 9.25	+ 7	+ 16	- 3	6	23.19	
May 29	II 1	D	21.4317	18.9620	+ 4	+ .2	+ .5	40 35 20.11	+ 1 2.46	- 3	+ 9	+ 3	6	22.72	69.9
			21.4357	19.3727	+ 6	+ .7	+2.3	40 37 14.31	- 52.18	+ 3	+ 40	- 2	7	22.61	69.4
			21.3003	21.5577	+ 4	-.4	-.1	40 36 28.89	- 6.52	- 0	- 8	0	8	22.37	
			33.6670 ^{iv}	10.7977 ⁱⁱ	+ 57	+1.7	+1.0	40 46 2.35	- 9 38.43	- 97	+ 40	-17	6	23.24	
			15.6523	27.3723	+155	-.6	+ .5	40 41 19.48	- 4 56.75	+ 16	- 3	- 9	6	22.83	69.4
			7.8933 ⁱⁱ	28.7387 ^{iv}	- 12	-.4	+ .4	40 27 34.57	+ 8 47.08	+1.00	- 1	+18	8	22.90	
			18.7373	22.1527	+ 13	+ .3	+ .3	40 34 57.02	+ 1 26.40	- 5	+ 9	+ 3	6	23.55	
			13.4973	29.4047	+201	-.6	-1.5	40 29 40.72	+ 6 42.75	- 21	- 28	+12	6	23.16	69.3
			11.6770	27.4983	- 58	.0	+1.4	40 43 3.06	- 6 39.92	+ 21	+ 18	-14	9	23.48	70.1
			32.9617 ^{iv}	8.5630 ⁱⁱ	+ 30	+ .9	-.8	40 46 41.24	-10 17.04	- 95	+ 43	-24	11	23.55	
May 30	II 1	R	34.4820 ^{iv}	9.3677 ⁱⁱ	+ 88	-1.0	-.7	40 25 46.54	+10 35.28	+ 94	- 25	+18	5	22.74	70.3
			32.2850 ^{iv}	7.3647 ⁱⁱ	- 8	-.8	-.1	40 25 52.49	+10 30.13	+ 95	- 14	+19	6	23.68	
			12.6780	24.2077	-157	+ .8	+ .7	40 31 31.84	+ 4 51.15	- 15	+ 22	+10	7	23.23	68.4
			21.6370	17.9033	- 9	+ .5	+ .3	40 37 57.11	- 1 34.39	+ 5	+ 12	- 3	6	22.92	68.3
			19.4893	21.2083	+ 3	-.2	-.7	40 37 6.29	- 43.48	+ 2	- 12	- 1	6	22.76	
			23.3887	16.8920	+ 9	+ .8	-.2	40 33 38.72	+ 2 44.30	- 9	- 15	+ 4	6	22.88	68.4
			27.1227	13.1613	+ 17	+ .3	+ .1	40 42 16.20	- 5 53.08	+ 19	+ 6	-10	5	23.32	68.4
			24.1530	17.8063	+ 55	-1.1	-1.0	40 39 4.25	- 2 40.63	+ 9	- 30	- 4	6	23.43	80.0
			19.1713	24.2953	+ 79	+1.2	+ .7	40 38 32.38	- 2 9.77	+ 7	+ 28	- 3	6	22.99	
			17.7260	20.2033	- 22	+ .7	+ .5	40 35 20.32	+ 1 2.59	- 3	+ 17	+ 3	6	23.14	79.2
June 7	II 1	D	20.1123	22.1670	+ 20	+ .5	.0	40 37 14.51	- 52.01	+ 3	+ 8	- 2	7	22.66	78.6
			20.9113	20.6463	+ 2	-.2	-.6	40 36 29.09	- 6.71	- 0	- 10	0	8	22.36	
			9.4743 ⁱⁱ	32.3443 ^{iv}	+ 22	+ .3	-.1	40 46 2.58	- 9 38.36	- 97	+ 3	-17	6	23.17	77.4
			25.9797	14.2317	+ 11	+1.0	+1.1	40 41 19.72	- 4 57.10	+ 16	+ 30	- 9	6	23.05	
			31.6163 ^{iv}	10.7833 ⁱⁱ	+ 7	+ .7	+ .3	40 27 34.78	+ 8 46.82	+1.00	+ 15	+18	8	23.01	77.6
			23.2053	19.8020	+ 44	+ .7	+ .2	40 34 57.26	+ 1 26.17	- 5	+ 13	+ 3	6	23.60	
			30.1153	14.2613	+300	+1.0	+ .6	40 29 40.97	+ 6 41.65	- 21	+ 23	+12	6	22.82	77.4
			27.5983	11.7813	- 43	-.4	+ .3	40 43 3.29	- 6 39.85	+ 21	- 2	-14	9	23.58	75.4
			6.8187 ⁱⁱ	31.2177 ^{iv}	- 41	.0	+ .2	40 46 41.47	-10 16.87	- 95	+ 2	-24	11	23.54	
			7.4980 ⁱⁱ	32.6020 ^{iv}	+ 2	+1.7	+ .2	40 25 46.80	+10 34.80	+ 94	+ 30	+18	5	23.07	
June 7	II 1	D	6.9937 ⁱⁱ	31.8797 ^{iv}	- 23	+ .8	.0	40 25 52.75	+10 29.23	+ 95	+ 13	+19	6	23.31	73.9
			26.1163	14.6037	+ 35	-.1	-.3	40 31 32.08	+ 4 51.20	- 15	- 5	+10	7	23.25	
			19.3837	23.1080	+ 40	-1.1	-.3	40 37 57.36	- 1 34.28	+ 5	- 21	- 3	6	22.95	73.5
			21.5640	19.8287	+ 9	+ .2	.0	40 37 6.40	- 43.90	+ 2	+ 3	- 1	6	22.60	
			16.8610	23.3503	+ 6	-.9	.0	40 33 38.96	+ 2 44.11	- 9	- 14	+ 4	6	22.94	
			14.5947	28.5303	+188	-1.2	-.8	40 42 16.43	- 5 52.86	+ 19	- 29	-10	5	23.42	74.3
			18.8887	24.8287	+ 89	+1.4	+1.1	40 39 5.92	- 2 43.07	+ 9	+ 36	- 4	6	23.32	62.8
			22.5760	17.3740	- 1	+ .4	+ .6	40 38 34.13	- 2 11.54	+ 7	+ 14	- 3	6	22.83	63.4
			22.5817	20.2090	+ 29	+ .4	+1.1	40 35 22.19	+ 1 0.07	- 3	+ 20	+ 3	6	22.52	63.1
			21.6313	19.4920	+ 8	+ .9	+1.5	40 37 16.29	- 0 54.12	+ 3	+ 33	- 2	7	22.58	
June 7	II 1	D	20.3100	20.6490	+ 1	+ .5	+ .3	40 36 30.87	- 8.57	+ 0	+ 12	0	8	22.50	62.3
			32.1707 ^{iv}	9.2097 ⁱⁱ	+ 17	+1.5	.0	40 46 4.62	- 9 40.65	- 97	+ 24	-17	6	23.13	
			14.0543	25.9080	- 5	+ .4	.0	40 41 21.85	- 4 59.73	+ 16	+ 6	- 9	6	22.31	60.9
			9.7050 ⁱⁱ	30.4540 ^{iv}	+ 1	+2.0	+1.9	40 27 36.79	+ 8 44.68	+1.00	+ 56	+18	8	23.29	
			19.8670	23.1640	+ 44	+1.1	+ .4	40 34 59.46	+ 1 23.48	- 5	+ 22	+ 3	6	23.20	

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
June 7	II 10	D	13.0063	28.7970	+125	+1.4	+ .2	40 29 43.26	+ 6 39.61	- 21	+ 25	+12	6	23.09	60.6
	III 1	D	13.2877	29.2020	+172	+ .2	+ .1	40 43 5.57	- 6 42.86	+ 21	+ 4	-14	9	22.91	59.8
	2		32.7150 ^{iv}	8.2147 ⁱⁱ	+ 18	+ .6	+ .6	40 46 43.72	-10 19.58	- 95	+ 17	-24	11	23.25	57.8
	3		34.6850 ^{iv}	9.6937 ⁱⁱ	+ 96	- .9	- .4	40 25 49.37	+10 32.19	+ 94	- 19	+18	5	22.54	
	4		32.5980 ^{iv}	7.7937 ⁱⁱ	+ 9	-1.8	-1.5	40 25 55.28	+10 27.24	+ 95	- 48	+19	6	23.24	
	5		13.5697	24.9813	- 73	- .3	- .4	40 31 34.50	+ 4 48.88	- 15	- 10	+10	7	22.80	56.6
	6		22.5513	18.7393	+ 22	+ .3	- .8	40 37 59.87	- 1 36.45	+ 5	- 5	- 3	6	23.45	
	7		19.7343	21.5827	+ 9	+1.3	+1.5	40 37 8.83	- 46.76	+ 2	+ 40	- 1	6	22.54	
	8		24.2300	17.8223	+ 58	-1.0	-1.2	40 33 41.46	+ 2 42.18	- 9	- 31	+ 4	6	23.34	
	9		29.0423	15.0190	+247	-1.0	-1.5	40 42 18.86	- 5 55.23	+ 19	- 35	-10	5	23.42	56.8
June 8	II 1	R	24.1690	17.7060	+ 54	+1.5	+1.2	40 39 6.07	- 2 43.56	+ 9	+ 39	- 4	6	23.01	66.3
	2		18.2847	23.4903	+ 42	+ .8	+ .4	40 38 34.30	- 2 11.74	+ 7	+ 18	- 3	6	22.84	
	3		20.1353	22.5097	+ 28	+ .2	+1.1	40 35 22.37	+ 1 0.11	- 3	+ 17	+ 3	6	22.71	65.1
	4		19.8990	22.0437	+ 18	+ .4	- .2	40 37 16.47	- 54.28	+ 3	+ 4	- 2	7	22.31	
	5		21.3490	21.0060	+ 3	.0	- .5	40 36 31.05	- 8.68	- 0	- 6	0	8	22.39	
	6		9.3100 ⁱⁱ	32.2683 ^{iv}	+ 20	-1.2	-1.5	40 46 4.82	- 9 40.59	- 97	- 38	-17	6	22.77	
	7		25.2997	13.4573	- 65	- .9	-1.3	40 41 22.08	- 4 59.29	+ 16	- 31	- 9	6	22.61	63.9
	8		30.1337 ^{iv}	9.3610 ⁱⁱ	- 2	- .4	- .4	40 27 36.99	+ 8 45.27	+1.00	- 11	+18	8	23.41	
	9		22.1797	18.8700	+ 15	+1.2	+ .3	40 34 59.69	+ 1 23.73	- 5	+ 23	+ 3	6	23.69	
	10		28.2003	12.4153	+ 41	+ .2	+ .8	40 29 43.51	+ 6 39.26	- 21	+ 13	+12	6	22.87	63.1
June 9	III 1	R	28.6140	12.7123	+ 91	-1.2	- .8	40 43 5.84	- 6 42.33	+ 21	- 29	-14	9	23.38	61.0
	2		10.0540 ⁱⁱ	34.5417 ^{iv}	+ 91	- .7	+ .2	40 46 44.06	-10 19.44	- 95	- 8	-24	11	23.46	
	3		6.6037 ⁱⁱ	31.6060 ^{iv}	- 42	+1.4	.0	40 25 49.68	+10 32.12	+ 94	+ 22	+18	5	23.19	59.8
	4		7.2743 ⁱⁱ	32.0743 ^{iv}	- 15	- .9	- .4	40 25 55.59	+10 27.07	+ 95	- 19	+19	6	23.67	
	5		28.0053	16.6190	+227	-1.1	- .5	40 31 34.80	+ 4 48.50	- 15	- 24	+10	7	23.08	58.9
	6		18.5807	22.4400	+ 18	- .1	.0	40 38 0.19	- 1 37.63	+ 5	- 1	- 3	6	22.63	58.4
	7		21.4267	19.5900	+ 6	- .2	- .6	40 37 9.35	- 46.46	+ 2	- 10	- 1	6	22.86	
	8		18.3747	24.7207	+ 85	- .7	+ .5	40 33 41.78	+ 2 40.68	- 9	- 4	+ 4	6	22.43	
	9		13.8253	27.8707	+103	-2.0	-1.2	40 42 19.17	- 5 55.42	+ 19	- 47	-10	5	23.42	58.8
	II 1	D	17.1897	23.6450	+ 24	.0	- .6	40 39 6.22	- 2 43.29	+ 9	- 7	- 4	6	22.97	69.4
June 10	2		22.1483	16.9603	- 19	.0	.0	40 38 34.44	- 2 11.14	+ 7	0	- 3	6	23.40	69.4
	3		21.9847	19.5997	+ 15	.0	+1.3	40 35 22.55	+ 1 0.35	- 3	+ 16	+ 3	6	23.12	68.6
	4		20.5217	18.3697	- 10	.0	+1.0	40 37 16.63	- 54.39	+ 3	+ 13	- 2	7	22.45	
	5		18.3230	18.6603	- 5	+1.0	+ .7	40 36 31.21	- 8.52	+ 0	+ 25	0	8	23.02	
	6		30.7057 ^{iv}	7.7273 ⁱⁱ	- 20	+1.2	+ .7	40 46 5.02	- 9 41.00	- 97	+ 28	-17	6	23.22	
	7		14.2023	26.0520	+ 13	.0	+ .2	40 41 22.29	- 4 59.67	+ 16	+ 2	- 9	6	22.77	67.4
	8		9.5247 ⁱⁱ	30.2777 ^{iv}	- 1	+1.3	+1.7	40 27 37.19	+ 8 44.77	+1.00	+ 43	+18	8	23.65	
	9		16.7587	20.0343	- 47	+ .7	+1.1	40 34 59.91	+ 1 22.71	- 5	+ 25	+ 3	6	22.91	
	10		12.5320	28.2913	+ 55	.0	+ .4	40 29 43.74	+ 6 38.64	- 21	+ 5	+12	6	22.40	65.6
	III 2	D	30.5783 ^{iv}	6.0607 ⁱⁱ	- 66	- .2	- .4	40 46 44.23	-10 19.80	- 95	- 8	-24	11	23.27	65.8
June 11	3		34.4747 ^{iv}	9.5160 ⁱⁱ	+ 88	- .7	+ .2	40 25 49.98	+10 31.35	+ 94	- 8	+18	5	22.42	
	4		31.2170 ^{iv}	6.4213 ⁱⁱ	- 53	-1.9	-1.4	40 25 55.88	+10 26.87	+ 95	- 48	+19	6	23.47	63.6
	5		13.0320	24.4347	-127	- .5	- .7	40 31 35.08	+ 4 48.02	- 15	- 17	+10	7	22.95	
	6		22.3390	18.4723	+ 13	- .7	- .4	40 38 0.48	- 1 37.81	+ 5	- 16	- 3	6	22.59	63.1
	7		19.2793	21.1253	+ 1	- .7	- .8	40 37 9.65	- 46.68	+ 2	- 21	- 1	6	22.83	63.2
	8		25.6367	19.2757	+134	-1.6	- .4	40 33 42.08	+ 2 41.19	- 9	- 30	+ 4	6	22.98	
	9		27.7983	13.7207	+ 93	- .2	- .4	40 42 19.47	- 5 56.21	+ 19	- 8	-10	5	23.32	62.4
	II 1	R	24.8550	18.3853	+ 91	+1.6	+1.2	40 39 6.51	- 2 43.83	+ 9	+ 41	- 4	6	23.20	71.3
	2		17.5980	22.8203	+ 9	.0	.0	40 38 34.76	- 2 12.08	+ 7	0	- 3	6	22.78	70.3
	3		19.5537	21.9357	+ 14	- .6	- .9	40 35 22.89	+ 1 0.27	- 3	- 21	+ 3	6	23.01	
June 12	4		20.1167	22.2550	+ 22	+ .9	.0	40 37 16.95	- 54.13	+ 3	+ 14	- 2	7	23.04	
	5		21.2330	20.8940	+ 1	-1.8	- .8	40 36 31.53	- 8.57	0	- 39	0	8	22.65	
	6		8.9250 ⁱⁱ	31.8933 ^{iv}	+ 11	-1.6	- .6	40 46 5.40	- 9 40.82	- 97	- 33	-17	6	23.17	
	7		26.3537	14.4820	+ 43	+1.1	+ .4	40 41 22.69	- 5 0.31	+ 16	+ 22	- 9	6	22.73	70.1
	8		31.1360 ^{iv}	10.3847 ⁱⁱ	+ 2	+ .1	- .5	40 27 37.56	+ 8 44.74	+1.00	- 5	+18	8	23.51	

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
June 11	II 9	R	22.5973	19.3177	+ 27	+ .4	+ .7	40 35 0.33	+ 1 23.00	— 5	+ 15	+ 3	6	23.52	69.6
		10	28.9590	13.2180	+148	+ .5	+ .3	40 29 44.18	+ 6 38.41	— 21	+ 12	+12	6	22.68	
	III 1	R	29.8933	13.9723	+268	— .6	+ .3	40 43 6.55	+ 6 43.27	+ 21	— 5	—14	9	23.39	
		2	8.4637 ⁱⁱ	32.9933 ^{iv}	+ 28	— .2	.0	40 46 44.69	—10 20.34	— 95	— 3	—24	11	23.24	
	3	7.7077 ⁱⁱ	32.6773 ^{iv}	+ 8	+1.6	+ .4	40 25 50.53	+10 31.42	+ 94	+ 30	+18	5	23.42		
	4	6.3417 ⁱⁱ	31.0987 ^{iv}	— 56	+ .1	+ .2	40 25 56.42	+10 25.88	+ 95	+ 4	+19	6	23.54		
	5	26.7723	15.4273	+108	— .2	— .6	40 31 35.61	+ 4 47.15	— 15	— 10	+10	7	22.68		
	6	19.9240	23.7963	+ 64	—1.9	—2.1	40 38 1.04	— 1 38.08	+ 5	— 57	— 3	6	22.47		
	7	20.3847	18.5023	— 8	+ .6	— .1	40 37 10.19	+ 47.58	+ 2	+ 8	— 1	6	22.76		
	8	17.1523	23.4870	— 8	— .3	.0	40 33 42.54	+ 2 40.16	— 9	— 5	+ 4	6	22.66		
June 14	II 9	D	12.8070	26.8940	— 19	—2.1	— .7	40 42 20.02	— 5 56.17	+ 19	— 42	—10	5	23.57	
		1	17.7133	24.1957	+ 55	— .7	—1.6	40 39 7.02	— 2 44.06	+ 9	— 31	— 4	6	22.76	
	2	22.9047	17.6637	+ 13	+1.0	— .1	40 38 35.31	— 2 12.56	+ 7	+ 14	— 3	6	22.99		
	3	21.6937	19.3387	+ 13	—1.9	.0	40 35 23.47	+ 59.58	— 3	— 30	+ 3	6	22.81		
	4	21.4490	19.2847	+ 5	— .6	— .1	40 37 17.50	+ 54.74	+ 3	— 11	— 2	7	22.73		
	5	20.8583	21.2147	+ 1	— .6	—1.8	40 36 32.09	— 9.01	+ 0	— 32	0	8	22.84		
	6	31.6827 ^{iv}	8.6793 ⁱⁱ	+ 4	+ .9	+ .2	40 46 6.04	— 9 41.69	— 97	+ 17	—17	6	23.44		
	7	15.3190	27.1960	+129	—1.1	— .2	40 41 23.36	— 5 0.66	+ 16	— 20	— 9	6	22.63		
	8	9.6980 ⁱⁱ	30.4120 ^{iv}	+ 1	— .2	+1.8	40 27 38.18	— 8 43.79	+1.00	+ 33	+18	8	23.56		
	10	14.2817	29.9997	+292	+ .9	.0	40 29 44.91	+ 6 38.20	— 21	+ 14	+12	6	23.22		
June 23	II 1	R	24.2227	17.7297	+ 55	— .1	— .4	40 39 7.41	— 2 44.33	+ 9	+ 6	— 4	6	23.25	
		1	23.7430	17.2060	+ 27	+ .4	+ .8	40 39 8.11	— 2 45.37	+ 9	+ 16	— 4	6	23.01	
	2	17.8683	23.1787	+ 24	+1.4	+1.1	40 38 36.77	— 2 14.34	+ 7	+ 36	— 3	6	22.89		
	3	19.7780	22.0423	+ 17	+1.7	+ .4	40 35 25.10	+ 57.30	— 3	+ 32	+ 3	6	22.78		
	4	22.5267	24.7527	+ 71	— .6	— .1	40 37 19.07	+ 56.47	+ 3	— 11	— 2	7	22.57		
	5	21.3457	20.9237	+ 3	— .4	—1.2	40 36 33.69	— 10.68	— 0	— 22	0	8	22.87		
	6	8.3750 ⁱⁱ	31.4657 ^{iv}	— 3	+ .6	+ .1	40 46 7.92	— 9 43.88	— 97	+ 11	—17	6	23.07		
	7	27.1063	15.1240	+116	+1.6	+ .6	40 41 25.39	— 5 3.29	+ 16	+ 33	— 9	6	22.56		
	8	31.2247 ^{iv}	10.5940 ⁱⁱ	+ 3	— .2	— .1	40 27 39.88	+ 8 41.69	+1.00	— 4	+18	8	22.79		
	9	23.1967	20.0357	+ 45	+1.2	+ .7	40 35 3.16	+ 1 20.05	— 5	+ 28	+ 3	6	23.53		
June 25	III 1	D	27.7537	12.1127	— 10	+1.4	+1.3	40 29 47.17	+ 6 35.48	— 21	+ 39	+12	6	23.01	
		2	14.1547	30.2363	+309	+ .1	— .1	40 43 10.23	— 6 47.43	+ 21	0	—14	9	22.96	
	3	32.4520 ^{iv}	7.7807 ⁱⁱ	+ 6	— .7	— .9	40 46 48.88	—10 23.37	— 95	— 22	—24	11	23.21		
	4	33.8760 ^{iv}	9.0720 ⁱⁱ	+ 63	—3.2	—2.5	40 25 54.86	+10 27.37	+ 94	— 83	+18	5	22.57		
	5	34.4643 ^{iv}	9.6690 ⁱⁱ	+ 87	— .8	— .3	40 26 0.70	+10 22.16	+ 95	— 17	+19	6	23.89		
	6	13.7650	24.9910	— 62	+ .2	—1.1	40 31 39.76	+ 4 43.71	— 15	— 11	+10	7	23.38		
	7	21.5280	17.4810	— 19	— .4	—1.0	40 38 5.37	— 1 42.29	+ 5	— 19	— 3	6	22.97		
	8	20.9603	23.0240	+ 35	— .6	— .2	40 37 14.59	— 52.27	+ 2	— 12	— 1	6	22.27		
	9	24.1300	17.9380	+ 57	—2.2	—1.8	40 33 47.07	+ 2 36.72	— 9	— 58	+ 4	6	23.22		
	28	26.0660	11.7820	—135	— .4	— .9	40 42 24.38	— 6 0.85	+ 19	— 18	—10	5	23.49		
June 28	II 2	D	21.2943	15.9797	— 64	—1.2	— .9	40 38 37.37	— 2 14.23	+ 7	— 31	— 3	6	22.93	
		3	21.7467	19.5137	+ 11	— .8	+1.0	40 35 25.81	+ 56.49	— 3	0	+ 3	6	22.36	
	4	21.2400	18.9697	+ 1	+ .8	+1.7	40 37 19.75	— 57.41	+ 3	+ 35	— 2	7	22.77		
	5	20.1957	20.6820	+ 2	+1.2	+ .5	40 36 34.35	— 12.30	— 0	+ 26	0	8	22.39		
	6	32.3000 ^{iv}	9.1687 ⁱⁱ	+ 20	+1.0	+ .6	40 46 8.72	— 9 44.97	— 97	+ 23	—17	6	22.90		
	7	17.4157	22.7307	+ 3	— .4	— .8	40 38 37.52	— 2 14.41	+ 7	— 18	— 3	6	23.03		
	8	20.1890	22.4210	+ 26	+ .6	+ .2	40 35 25.96	+ 56.51	— 3	+ 12	+ 2	6	22.64		
	9	21.0497	23.3063	+ 44	—1.0	—1.5	40 37 19.89	+ 57.17	+ 3	— 40	— 2	7	22.40		
	29	12.0237	28.2757	+ 21	+3.3	+1.5	40 43 13.66	— 6 51.01	+ 24	+ 72	—15	9	23.55		
	30	32.5520 ^{iv}	7.7333 ⁱⁱ	+ 7	— .1	+ .3	40 46 51.87	—10 27.60	— 91	+ 2	—25	11	23.24		
July 9	III 1	D	32.3327 ^{iv}	7.7103 ⁱⁱ	+ 1	—1.6	— .7	40 25 59.02	+10 22.62	+ 92	— 34	+18	5	22.45	
		2	33.4710 ^{iv}	9.0440 ⁱⁱ	+ 50	—2.6	—1.8	40 26 4.84	+10 17.81	+ 92	— 64	+19	6	23.18	
	3	14.2653	25.3157	— 21	— .5	— .8	40 31 43.83	+ 4 39.39	— 16	— 18	+ 9	7	23.03		
	4	21.6767	17.4547	— 17	+ .6	+ .1	40 38 9.80	— 1 46.72	+ 6	+ 12	— 3	6	23.29		
	5	18.4700	20.6940	— 7	—1.0	—1.2	40 37 19.00	— 56.22	+ 4	— 31	— 2	6	22.55		
	6														
	7														
	8														
	9														
	10														

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther. mom.
						A	B		Micrometer.	δ	l	r	Mer		
July 9	III 8	D	22.4037	16.4300	-32	+1.2	+1.6	40 33 51.56	+ 2 30.97	- 9	+ 40	+ 4	6	22.94	
			26.9293	12.4327	-46	+1.6	+ .2	40 42 28.86	- 6 6.46	+ 22	+ 28	-10	5	22.85	68.1
	IV 1	D	19.8273	17.8827	-18	- .3	- .6	40 37 12.07	- 49.13	+ 3	- 12	- 2	13	22.96	63.6
			21.5510	22.9260	+ 27	-3.3	-2.7	40 36 58.27	- 34.84	+ 2	- 87	- 2	11	22.67	
	3		12.6893	28.8013	+105	+ .6	- .6	40 29 34.94	+ 6 47.69	- 23	+ 2	+12	7	22.61	64.0
	4		22.9277	17.3900	+ 7	- .4	- .4	40 38 42.38	- 2 20.05	+ 8	- 11	- 5	10	22.35	63.6
	5		12.4733	29.0767	+110	.0	-1.3	40 29 22.33	+ 7 0.12	- 24	- 16	+12	6	22.23	63.2
	6		30.6843 ^{iv}	11.6910 ⁱⁱ	- 9	- .9	+ .1	40 28 21.38	+ 8 0.26	+1.00	- 13	+13	5	22.69	
	7		14.0257	28.6473	+171	+1.7	+1.7	40 30 12.25	+ 6 10.17	- 21	+ 49	+10	6	22.86	
	8		27.8570	11.4503	- 50	- .5	- .5	40 43 18.07	+ 6 54.75	+ 24	- 14	-13	7	23.36	62.9
July 10	9		18.9233	22.7583	+ 28	+2.4	+3.1	40 37 58.95	- 1 37.05	+ 6	+ 78	- 3	11	22.82	
	10		17.0430	26.5627	+151	-1.1	+ .2	40 40 24.22	- 4 1.10	+ 14	- 15	- 7	6	23.10	61.9
	11		6.2153 ⁱⁱ	33.5000 ^{iv}	- 9	+1.8	- .1	40 24 51.80	+11 29.92	+ 88	+ 27	+20	6	23.13	61.8*
	III 1	R	27.9793	11.7290	- 22	-5.3	+ .7	40 43 13.86	- 6 50.86	+ 24	+ 17	-15	9	23.35	60.9
			7.5500 ⁱⁱ	32.5703 ^{iv}	+ 3	- .6	+ .1	40 46 52.08	-10 27.63	- 91	- 8	-25	11	23.32	62.6
	3		8.4627 ⁱⁱ	33.0730 ^{iv}	+ 24	+1.1	+ .1	40 25 59.27	+10 22.38	+ 92	+ 19	+18	5	22.99	62.0
	4		8.2467 ⁱⁱ	32.6333 ^{iv}	+ 17	+ .2	- .4	40 26 5.09	+10 16.70	+ 92	- 2	+19	6	22.94	
	5		25.9017	14.8890	+ 39	- .4	+ .4	40 31 44.08	+ 4 38.57	- 16	- 1	+ 9	7	22.64	61.1
	6		18.7977	23.0333	+ 34	+ .2	+ .8	40 38 10.07	- 1 47.19	+ 6	+ 13	- 3	6	23.10	60.4
	7		22.3383	20.0600	+ 24	+1.8	+1.4	40 37 19.28	- 57.67	+ 4	+ 47	- 2	6	22.16	60.0
July 12	8		18.6297	24.5760	+ 84	+ .6	+ .9	40 33 51.84	+ 2 30.58	- 9	+ 21	+ 4	6	22.64	
	9		13.0013	27.4973	+ 33	+1.7	+1.6	40 42 29.24	- 6 6.64	+ 22	+ 48	-10	5	23.25	59.3
	III 1	D	12.9390	29.1983	+159	+ .8	+ .2	40 43 14.29	- 6 51.55	+ 24	+ 15	-15	9	23.07	66.8
			34.2687 ^{iv}	9.4357 ⁱⁱ	+ 78	.0	.0	40 46 52.52	-10 28.14	- 91	0	-25	11	23.33	
	3		33.3723 ^{iv}	8.7760 ⁱⁱ	+ 45	-2.0	-1.0	40 25 59.81	+10 22.07	+ 92	- 45	+18	5	22.58	
	4		34.8713 ^{iv}	10.5027 ⁱⁱ	+102	- .2	-1.0	40 26 5.62	+10 16.46	+ 92	- 16	+19	6	23.09	
	5		13.8503	24.8830	- 62	- .3	- .6	40 31 44.60	+ 4 38.82	- 16	- 12	+ 9	7	23.30	66.1
	6		21.9190	17.6607	- 8	+ .8	-1.1	40 38 10.63	- 1 47.66	+ 6	- 1	- 3	6	23.05	
	7		18.1017	20.3673	- 15	+ .1	+ .1	40 37 19.84	- 57.25	+ 4	+ 3	- 2	6	22.70	66.4
	8		23.8583	17.9020	+ 47	-1.4	-2.0	40 33 52.41	+ 2 30.73	- 9	- 48	+ 4	6	22.67	65.8
July 16	9		26.2900	11.7940	-120	-1.4	-1.2	40 42 29.70	- 6 6.25	+ 22	- 43	-10	5	23.19	65.8
	IV 1	R	21.3387	23.3067	+ 42	- .2	- .1	40 37 12.77	- 49.87	+ 3	- 4	- 2	13	23.00	64.1 ^a
			20.4257	19.0227	- 2	-1.6	-1.5	40 36 58.99	- 35.47	+ 2	- 44	- 2	11	23.19	65.0
	3		28.3563	12.2670	+ 40	- .5	.0	40 29 35.72	+ 6 46.96	- 23	- 8	+12	7	22.56	"
	4		19.4160	24.9667	+105	+ .2	+ .6	40 38 43.09	- 2 20.62	+ 8	+ 10	- 5	10	22.70	64.3
	5		28.7690	12.1747	+ 67	- .3	.0	40 29 23.11	+ 6 59.79	- 24	- 5	+12	6	22.79	
	6		10.4300 ⁱⁱ	29.3837 ^{iv}	0	+1.8	+1.1	40 28 22.15	+ 7 59.28	+1.00	+ 43	+13	5	23.04	64.3
	8		13.3633	29.7870	+225	+ .4	+ .5	40 43 18.79	- 6 55.87	+ 24	+ 13	-13	7	23.23	64.3 ^d
	III 1	R	31.3050	15.0590	+450	- .6	+ .1	40 43 15.30	- 6 51.95	+ 24	- 8	-15	9	23.45	65.3
			8.0400 ⁱⁱ	32.9140 ^{iv}	+ 20	-1.1	- .1	40 46 53.56	-10 29.03	- 91	- 19	-25	11	23.29	
	3		5.9057 ⁱⁱ	30.4547 ^{iv}	- 72	+1.6	+1.9	40 26 1.03	+10 20.58	+ 92	+ 50	+18	5	23.26	
July 16	4		5.8500 ⁱⁱ	30.1907 ^v	- 75	- .6	.0	40 26 6.84	+10 15.31	+ 92	- 9	+19	6	23.23	
	7		22.7703	20.4620	+ 33	- .5	- .3	40 37 21.16	- 58.45	+ 4	- 12	- 2	6	22.67	66.1
	8		19.3490	25.2287	+118	- .5	+ .6	40 33 53.75	+ 2 28.98	- 9	0	+ 4	6	22.74	
	9		12.5180	27.0713	- 29	-1.1	- .4	40 42 31.04	- 6 7.93	+ 22	- 22	-10	5	23.06	64.6
	IV 1	D	18.2037	16.1787	- 51	+ .5	- .1	40 37 13.90	- 51.08	+ 3	+ 6	- 2	13	23.02	64.4
			21.0527	22.5147	+ 24	- .3	+1.2	40 37 0.13	- 37.03	+ 2	+ 10	- 2	11	23.31	
	3		16.8137	32.8353	+672	- .4	- .6	40 29 36.94	+ 6 46.83	- 23	- 14	+12	7	23.59	
	4		22.5293	16.9120	- 15	+ .5	- .2	40 38 44.22	- 22.01	+ 8	+ 5	- 5	10	22.39	64.4
	5		12.2793	28.8373	+ 79	- .5	-1.5	40 29 24.33	+ 6 58.90	- 24	- 27	+12	6	22.90	
	6		30.6567 ^{iv}	11.7233 ⁱⁱ	- 11	-3.0	-1.9	40 28 23.34	+ 7 58.74	+1.00	- 72	+13	5	22.54	64.1
	7		13.2600	27.8180	+ 67	+1.0	+1.3	40 30 14.17	+ 6 8.29	- 21	+ 32	+10	6	22.73	
	8		27.1617	10.6780	-156	+ .7	- .6	40 43 19.88	- 6 56.42	+ 24	+ 3	-13	7	23.67	
	9		18.0097	21.8687	- 2	- .2	- .9	40 38 0.52	- 1 37.58	+ 6	- 14	- 3	11	22.94	
	10		16.1557	25.7617	+ 80	- .7	- .1	40 40 25.94	- 4 3.11	+ 14	- 12	- 7	6	22.84	63.8

* Hurried and e. e. f.

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther- mom.
						A	B		Micrometer.	δ	l	r	Mer		
July 16	IV 11	D	6.9623 ⁱⁱ	34.1857 ^{iv}	+ 39	— .1	— .1	40 24 53.44	+11 28.49	+ 88	— 3	+20	6	23.04	64.0
July 18	III 1	D	26.0337	13.5750	— 25	+ .2	— 1.8	40 41 37.31	— 5 14.98	+ 19	— 20	— 10	7	22.29	69.8
			13.2100	29.5270	+192	+ .7	+ 1.1	40 43 15.79	— 6 53.09	+ 24	+ 25	— 15	9	23.13	68.6
			33.3750 ^{iv}	8.4653 ⁱⁱ	+ 41	+ .9	— 1.4	40 46 54.07	— 10 29.99	— 91	— 3	— 25	11	23.00	
			33.7343 ^{iv}	9.2313 ⁱⁱ	+ 59	— 1.0	— 1.3	40 26 1.63	+10 19.75	+ 92	— 32	+18	5	22.21	
			32.4790 ^{iv}	8.1763 ⁱⁱ	+ 13	— .5	— .7	40 26 7.45	+10 14.57	+ 92	— 17	+19	6	23.02	
			14.6930	25.6330	+ 16	— .6	— .5	40 31 46.42	+ 4 36.68	— 16	— 16	+ 9	7	22.94	67.3
			22.0387	17.7177	— 6	.0	.0	40 38 12.58	— 1 49.25	+ 6	0	— 3	6	23.42	
			18.9940	21.5243	+ 5	— 2.0	— .2	40 37 21.83	— 58.94	+ 4	— 34	— 2	6	22.63	67.6
			22.8820	17.0163	— 2	— .4	— .1	40 33 54.44	+ 2 28.32	— 9	— 8	+ 4	6	22.69	
			28.0423	13.4737	+ 96	+ 6	— 1.2	40 42 31.73	+ 6 8.64	+ 22	— 6	— 10	5	23.20	66.4
			21.5750	23.5943	+ 48	— .5	— .7	40 37 14.52	— 51.18	+ 3	— 17	— 2	13	23.31	63.9
			17.8937	16.4080	— 39	— 1.7	— 2.1	40 37 0.78	— 37.47	+ 2	— 54	— 2	11	22.88	
			30.4107	14.4193	+335	— 1.9	— .1	40 29 37.63	+ 6 45.22	— 23	— 32	+12	7	22.49	
			18.1380	23.7790	+ 48	— 1.1	+ .2	40 38 44.87	— 2 22.76	+ 8	— 15	— 5	10	22.09	63.5
			29.1507	12.6387	+128	— 1.3	— .2	40 29 25.03	+ 6 57.86	— 24	— 23	+12	6	22.60	63.5
			10.1543 ⁱⁱ	29.0247 ^{iv}	+ 3	+3.0	+1.3	40 28 24.02	+ 7 57.18	+1.00	+ 64	+13	5	23.02	62.5
			27.9000	13.3703	+ 80	— .8	— .3	40 30 14.85	+ 6 7.61	— 21	— 17	+10	6	22.24	
			10.9790	27.4700	—111	— 2.0	— .5	40 43 20.53	— 6 56.72	+ 24	— 38	— 13	7	23.61	
			21.5653	17.6790	— 14	— .5	— .8	40 38 1.09	— 1 38.24	+ 6	— 18	— 3	11	22.81	62.0
			24.8950	15.2590	+ 6	+1.1	.0	40 40 26.56	— 4 3.68	+ 14	+ 17	— 7	6	23.18	61.7
			33.7223 ^{iv}	6.5180 ⁱⁱ	+ 7	+ .2	— .1	40 24 54.04	+11 27.93	+ 88	+ 1	+20	6	23.12	
July 19	III 1	R	13.0230	25.4820	— 80	— 1.3	— .6	40 41 37.89	— 5 14.85	+ 19	— 28	— 10	7	22.92	61.5
			30.5280	14.2153	+334	— 2.0	— .1	40 43 16.02	— 6 53.34	+ 24	— 33	— 15	9	22.53	73.0
			7.7627 ⁱⁱ	32.6903 ^{iv}	+ 10	+ .5	+ .4	40 46 54.29	— 10 30.36	— 91	+ 13	— 25	11	23.01	73.1
			8.0710 ⁱⁱ	32.5827 ^{iv}	+ 14	+ .5	— .6	40 26 1.80	+10 19.86	+ 92	0	+18	5	22.81	
			6.4067 ⁱⁱ	30.7310 ^{iv}	— 55	— 1.6	+ .1	40 26 7.72	+10 14.94	+ 92	— 24	+19	6	23.59	
			26.7590	15.8650	+123	— .2	+ .1	40 31 46.69	+ 4 35.78	— 16	— 1	+ 9	7	22.46	72.9
			19.5070	23.8530	+ 64	— 1.0	— .3	40 38 12.88	— 1 50.06	+ 6	— 20	— 3	6	22.71	72.5
			21.2237	18.8640	0	— .2	.0	40 37 22.14	— 59.67	+ 4	— 3	— 2	6	22.52	72.4
			16.5063	22.3580	— 30	— .2	.0	40 33 54.76	+ 2 27.89	— 9	— 3	+ 4	6	22.63	
			12.4827	27.0873	— 28	— .9	— .1	40 42 32.05	— 6 9.23	+ 22	— 16	— 10	5	22.83	72.0
			19.5510	17.5103	— 26	+ .8	.0	40 37 14.83	— 51.54	+ 3	+ 13	— 2	13	23.56	69.0
			19.0267	20.5213	— 2	— 1.1	— .4	40 37 1.10	— 37.79	+ 2	— 22	— 2	11	23.20	
			11.8460	27.8400	— 21	+1.1	+ .2	40 29 37.96	+ 6 44.38	— 23	+ 20	+12	7	22.50	68.9
			22.4010	16.7307	— 22	+1.0	+2.4	40 38 45.19	— 2 23.33	+ 8	+ 46	— 5	10	22.45	
			13.1947	29.6737	+207	— .3	+ .2	40 29 25.37	+ 6 57.22	— 24	— 2	+12	6	22.51	
			29.3150 ^{iv}	10.4323 ⁱⁱ	+ 1	— .5	— .2	40 28 24.37	+ 7 57.48	+1.00	— 10	+13	5	22.93	69.2
			11.9517	26.5033	— 98	— .3	— .7	40 30 15.18	+ 6 7.71	— 21	— 14	+10	6	23.70	
			28.1620	11.6517	— 15	— .1	— 1.2	40 43 20.86	— 6 57.45	+ 24	— 17	— 13	7	22.42	
			19.1933	23.0897	+ 39	+ .9	+ .4	40 38 1.38	— 1 38.63	+ 6	+ 19	— 3	11	23.08	a d
			15.0010	24.6553	— 14	— 1.6	+ .3	40 40 26.87	— 4 4.09	+ 14	— 21	— 7	6	22.70	68.6
			5.5497 ⁱⁱ	32.7537 ^{iv}	— 55	+ .3	— 1.1	40 24 54.34	+11 27.76	+ 88	— 9	+20	6	23.15	68.2
July 25	III 1	D	24.7913	12.3107	— 159	— .6	— 1.6	40 41 38.18	— 5 15.19	+ 19	— 30	— 10	7	22.85	
			10.5623	26.9563	— 178	— .2	— .3	40 43 17.03	— 6 54.10	+ 24	— 7	— 15	9	23.04	65.5
			32.7280 ^{iv}	7.7433 ⁱⁱ	+ 11	+ .8	.0	40 46 55.39	— 10 31.81	— 91	+ 13	— 25	11	22.66	65.6
			33.5090 ^{iv}	9.0507 ⁱⁱ	+ 51	— 2.1	— 1.6	40 26 3.29	+10 18.60	+ 92	— 54	+18	5	22.50	
			33.6920 ^{iv}	9.4420 ⁱⁱ	+ 59	+ .3	— .6	40 26 9.00	+10 13.35	+ 92	— 2	+19	6	23.50	
			14.2367	25.1063	— 31	.0	— 1.1	40 31 48.10	+ 4 34.78	— 16	— 1	+ 9	7	22.87	
			31.8037	17.3993	— 16	+ .8	— 1.2	40 38 14.43	— 1 51.33	+ 6	— 2	— 3	6	23.17	65.1
			18.1513	20.5780	— 13	+ .5	+1.1	40 37 23.74	— 1 1.33	+ 4	+ 25	— 2	6	22.74	
			23.6043	17.8143	+ 37	+ .2	+ .7	40 33 56.41	+ 2 26.50	— 9	+ 14	+ 4	6	23.06	
			27.0430	12.3773	+ 38	+1.4	— .1	40 42 33.73	— 6 10.75	+ 23	+ 21	— 10	5	23.36	65.2
			20.5073	22.6213	+ 28	+ .2	— .4	40 37 16.42	— 53.53	+ 3	— 2	— 2	13	23.01	65.0a
			22.1343	20.5603	+ 18	— 2.3	— 1.3	40 37 2.75	— 39.85	+ 2	— 53	— 2	11	22.48	

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.						Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer			
July 25	IV 3 R		29.4373	13.5297	+204	— .2	—1.0	40 29 39.77	+ 6 42.77	— 23	— 16	+12	7	40 36 22.34	64.8	
		4	19.8973	25.5920	+137	+ .3	+1.8	40 38 46.87	— 2 24.35	+ 8	+ 28	— 5	10	22.93		
		6	10.6597 ⁱⁱ	29.4570 ^{iv}	0	+1.7	+ .9	40 28 26.22	+ 7 55.32	+1.00	+ 39	+13	5	23.11		
		7	28.6550	14.2217	+182	— .4	+1.0	40 30 17.01	+ 6 5.43	— 21	+ 6	+10	6	22.45	65.0	
		8	12.4197	29.0093	+100	+ .5	+ .4	40 43 22.51	— 6 59.75	+ 24	+ 13	—13	7	23.07		
		9	24.7970	20.8520	+ 98	— .2	— .6	40 38 2.94	— 1 40.00	+ 6	— 10	— 3	11	22.98		
		10	25.5073	15.7847	+ 55	+3.0	+ .7	40 40 28.60	— 4 5.99	+ 14	+ 57	— 7	6	23.31	64.3	
		11	35.9090 ^{iv}	8.8307 ⁱⁱ	+146	.0	+ .9	40 24 56.01	+11 25.09	+ 88	+ 11	+20	6	22.35		
	III 1 R	12	13.8173	26.3633	+ 10	+ .6	+ .7	40 41 39.80	— 5 17.27	+ 19	+ 18	—10	7	22.87	63.9	
		26	29.2993	12.9080	+158	— .4	+2.0	40 43 17.22	— 6 54.88	+ 24	+ 19	—15	9	22.71	67.7	
July 26	IV 2 D	3	7.2390 ⁱⁱ	31.7020 ^{iv}	— 20	— .5	+ .7	40 26 3.54	+10 18.54	+ 92	+ 1	+18	5	23.24	67.1	
		4	6.1810 ⁱⁱ	30.4230 ^{iv}	— 63	— .6	— .2	40 26 9.35	+10 12.83	+ 92	— 12	+19	6	23.23		
		5	26.7430	15.8850	+124	— .4	— .3	40 31 48.35	+ 4 34.88	— 16	— 10	+ 9	7	23.13	66.6	
		6	17.9550	22.3813	+ 9	— .1	— .6	40 33 14.70	— 1 51.95	+ 6	— 9	— 3	6	22.75	66.2	
		7	22.8047	20.3713	+ 33	+1.1	+ .5	40 37 24.01	— 1 1.62	+ 4	+ 24	— 2	6	22.71		
		8	19.1297	24.8847	+101	— .9	+ .6	40 33 56.69	+ 2 25.78	— 9	— 7	+ 4	6	22.41		
		9	12.4107	27.0937	— 34	—2.7	— .8	40 42 34.01	— 6 11.20	+ 22	— 53	—10	5	22.45	65.3	
	III 1 R	2	18.3900	19.9953	— 12	+ .4	+1.3	40 37 3.02	— 40.56	+ 2	+ 23	— 2	11	22.80	63.4	
		3	11.3733	27.3597	— 87	+1.4	+ .9	40 29 40.06	+ 6 44.02	— 23	+ 34	+12	7	[24.38]	<i>a</i>	
	July 28	IV 2 D	4	22.0520	16.3117	— 43	+ .1	— .1	40 38 47.14	— 2 25.04	+ 8	0	— 5	10	22.23	61.9
5			13.0350	29.4503	+179	— .1	— .1	40 29 27.52	+ 6 55.54	— 24	— 3	+12	6	22.97		
6			30.8380 ^{iv}	12.0330 ⁱⁱ	— 15	—1.2	—1.0	40 28 26.50	+ 7 55.48	+1.00	— 32	+13	5	22.84	62.1	
7			12.0357	26.4800	— 92	+2.0	+ .7	40 30 17.30	+ 6 5.02	— 21	+ 41	+10	6	22.68		
8			27.1497	10.5317	—171	+1.1	+1.6	40 43 22.88	— 6 59.78	+ 24	+ 38	—13	7	23.66		
9			19.0470	23.0023	+ 35	— .7	.0	40 38 3.18	— 1 40.11	+ 6	— 11	— 3	11	23.10	<i>a</i>	
10			16.6413	26.3470	+127	—2.0	—1.0	40 40 28.87	— 4 5.76	+ 14	— 45	— 7	6	22.79	61.7	
11			5.4990 ⁱⁱ	32.6350 ^{iv}	— 59	— .9	— .2	40 24 56.21	+11 26.03	+ 88	— 17	+20	6	23.21	62.3	
III 1 R		12	25.5280	12.9683	— 80	+ .3	—1.1	40 41 40.04	— 5 17.39	+ 19	— 9	—10	7	22.72		
		2	27.9883	11.5790	— 32	+ .1	+1.0	40 43 17.65	— 6 54.86	+ 24	+ 14	15	9	23.11	66.9	
July 29	IV 2 D	3	35.9697 ^{iv}	10.9867 ⁱⁱ	+153	+ .7	+2.3	40 46 56.04	—10 32.13	— 91	+ 40	—25	11	23.26		
		4	33.4233 ^{iv}	9.0243 ⁱⁱ	+ 48	—1.2	+ .6	40 26 4.07	+10 17.09	+ 92	— 12	+18	5	22.19		
		5	32.9283 ^{iv}	8.7337 ⁱⁱ	+ 29	+1.4	+ .3	40 26 9.89	+10 11.88	+ 92	+ 26	+19	6	23.20		
		6	14.5187	25.3700	— 5	— .7	—1.2	40 31 43.89	+ 4 34.38	— 16	— 26	+ 9	7	23.01	65.9	
		7	21.3193	16.8550	— 38	+2.4	+1.7	40 38 15.28	— 1 52.79	+ 6	+ 60	— 3	6	23.18	65.5	
		8	17.8430	20.3017	— 19	+ .2	—1.1	40 37 24.61	— 1 2.12	+ 4	— 11	— 2	6	22.46		
		9	23.8307	18.0833	+ 49	— .8	—1.1	40 33 57.31	+ 2 25.46	— 9	— 27	+ 4	6	22.51		
		10	27.1347	12.4417	— 29	+ .1	—1.4	40 42 34.62	— 6 11.46	+ 22	— 16	—10	5	23.17	64.9	
	III 1 D	1	18.1193	15.9580	— 54	— .4	— .6	40 37 17.21	— 54.52	+ 3	— 14	— 2	13	22.69	63.1	
		2	20.7133	19.1380	— 3	—2.2	—2.3	40 37 3.58	— 39.83	+ 2	— 65	— 2	11	23.21		
July 29	IV 2 D	3	29.4610	13.5807	+209	— .5	.0	40 29 40.66	+ 6 42.09	— 23	— 8	+12	7	22.63	61.9	
		4	20.3200	26.0357	+158	—1.4	— .3	40 38 47.70	— 2 24.93	+ 8	— 26	— 5	10	22.64		
		5	28.0817	11.6823	— 18	— .4	— .1	40 29 28.13	+ 6 54.64	— 24	— 8	+12	6	22.63		
		6	11.5573 ⁱⁱ	30.3250 ^{iv}	— 8	+1.4	— .1	40 28 27.11	+ 7 54.55	+1.00	+ 21	+13	5	23.05	61.2	
		7	27.5460	13.1203	+ 42	—3.3	—1.6	40 30 17.90	+ 6 4.89	— 21	— 73	+10	6	22.01		
		8	11.1437	27.7483	— 80	—1.3	— .7	40 43 23.47	— 6 59.67	+ 24	— 35	—13	7	23.63		
		9	22.0993	18.1223	+ 3	— .2	—1.1	40 38 3.67	— 1 40.55	+ 6	— 17	— 3	11	23.09	61.0	
		10	24.4153	14.6590	— 39	+2.3	+ .6	40 40 29.42	— 4 6.61	+ 14	+ 44	— 7	6	23.38		
	III 1 D	11	35.0520	7.9687	+ 95	—1.2	+ .1	40 24 56.79	+11 25.09	+ 88	— 18	+20	6	22.84		
		12	12.9930	25.5327	— 80	—1.1	—1.8	40 41 40.54	— 5 16.89	+ 19	— 40	—10	7	23.41	60.5	
July 29	III 1 D	1	11.4227	27.8497	— 53	+ .8	+ .5	40 43 17.88	— 6 55.25	+ 24	+ 19	—15	9	23.00	70.4	
		4	5.2773 ⁱⁱ	29.4847 ^{iv}	— 95	—1.5	— .6	40 26 10.14	+10 11.89	+ 92	— 31	+19	6	22.89	69.6	
		5	25.6340	14.8437	+ 22	— .2	— .2	40 31 49.17	+ 4 32.91	— 16	— 5	+ 9	7	22.03		
		6	18.7197	23.1843	+ 37	—1.0	— .4	40 38 15.59	— 1 52.99	+ 6	— 21	— 3	6	22.48	69.3	
		7	20.8363	18.3530	— 10	+1.6	.0	40 37 24.92	— 1 2.77	+ 4	+ 26	— 2	6	22.49		
8	17.8650	23.6070	+ 38	— .5	+ .2	40 33 57.62	+ 2 25.29	— 9	— 5	+ 4	6	22.87				

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Ther. mom.
						A	B		Micrometer.	δ	l	r	Mer		
July 29	III 9	R	12.4187	27.1360	-31	-.6	+.1	40 42 34.95	-6 12.07	+22	-8	-10	5	40 36 22.97	68.4
		IV 1	18.0893	20.2773	-15	+.8	+.6	40 37 17.51	-55.29	+3	+20	-2	13	22.56	66.9a
		2	18.5970	20.2297	-8	+.8	+.4	40 37 3.88	-41.27	+2	+18	-2	11	22.90	
		3	11.7543	27.6473	-43	+1.0	+.8	40 29 40.98	+6 41.77	-23	+26	+12	7	22.97	66.6a
	4		20.4740	14.7033	-121	+.6	+.3	40 38 48.01	-2 25.62	+8	+13	-5	10	22.65	
		5	12.1127	28.4800	+43	+.4	.0	40 29 28.46	+6 53.98	-24	+6	+12	6	22.44	66.3
		6	30.2137 ^{iv}	11.4463 ⁱⁱ	-7	-1.1	-.1	40 28 27.44	+7 54.55	+1.00	-19	+13	5	22.98	
		7	14.2620	28.6530	+184	+.7	+1.0	40 30 18.22	+6 4.37	-21	+24	+10	6	22.78	
		8	29.5047	12.8857	+173	+.5	-.3	40 43 23.76	-7 0.68	+24	+4	-13	7	23.30	
		9	17.1607	21.1657	-31	+.4	+1.1	40 38 3.95	-1 41.20	+6	+20	-3	11	23.09	65.6a
July 30	III 12	R	14.9690 ⁱⁱ	25.6880 ^{iv}	+34	-.6	+.6	40 40 29.73	-4 5.85	-1.14	-2	-7	6	22.71	65.6
		11	6.9523 ⁱⁱ	33.9983 ^{iv}	+31	+.4	+1.1	40 24 57.09	+11 23.98	+88	+20	+20	6	22.41	
		12	26.9470	14.3907	+73	+1.1	+2.2	40 41 40.80	-5 17.69	+19	+45	-10	7	23.72	d a
		2	30.7697	14.3887	+369	-1.9	-.8	40 43 18.09	-6 55.16	+24	-40	-15	9	22.71	66.7
	4	D	7.4113 ⁱⁱ	32.4030 ^{iv}	-4	-.7	-.8	40 46 56.50	-10 31.95	-91	-21	-25	11	23.29	65.2
		3	7.7847 ^{iv}	32.1627 ^{iv}	-1	+.6	+1.7	40 26 4.63	+10 16.44	+92	+31	+18	5	22.53	
		4	31.9987 ^v	7.8233 ⁱⁱ	-4	+.9	+.1	40 26 10.44	+10 11.31	+92	+16	+19	6	23.08	
		5	14.3687	25.1660	-22	+1.3	+.3	40 31 49.45	+4 32.97	-16	+25	+9	7	22.67	64.6
	6		23.2177	18.7677	+38	-1.2	-2.9	40 38 15.90	-1 52.62	+6	-56	-3	6	22.81	
		7	19.1120	21.5853	+6	-.8	-.1	40 37 25.24	-1 2 56	+4	-14	-2	6	22.62	62.1
July 31	III 1	D	22.5443	16.8170	-17	-.1	+.3	40 33 57.95	+2 24.78	-9	+2	+4	6	22.76	61.2
		9	27.2777	12.5310	-15	+.3	+.1	40 42 35.27	-6 12.86	+22	+6	-10	5	22.64	61.2
		2	11.9273	28.3670	+20	-.2	-.2	40 43 18.30	-6 55.76	+24	-5	-15	9	22.67	64.0
		3	32.4507 ^{iv}	7.4153 ⁱⁱ	-3	+1.4	+.4	40 46 56.72	-10 33.06	-91	+27	-25	11	22.88	63.5
	4	R	33.5893 ^{iv}	9.2000 ⁱⁱ	+55	-2.2	-2.1	40 26 4.89	+10 16.87	+92	-62	+18	5	22.29	
		5	5.9393 ⁱⁱ	30.1293 ^{iv}	-74	-1.3	-1.1	40 26 10.73	+10 11.50	+92	-35	+19	6	23.05	
		6	27.1520	16.3903	+165	.0	-.4	40 31 49.73	+4 32.55	-16	-5	+9	7	22.23	62.6
		7	19.2770	23.7530	+60	-.8	-.1	40 38 16.20	-1 53.34	+6	-14	-3	6	22.81	62.1
	8		19.8650	17.3727	-26	+.9	-.3	40 37 25.55	-1 2.96	+4	+10	-2	6	22.77	
		8	16.7953	22.5093	-18	+.7	+.2	40 33 58.27	+2 24.44	-9	+13	+4	6	22.85	
Aug. 3	IV 1	R	12.6013	27.3360	-7	-.9	-.2	40 42 35.60	-6 12.57	+22	-17	-10	5	23.03	61.9
		2	17.8257	20.0173	-21	+.7	+.1	40 37 18.13	-55.37	+3	+12	-2	13	23.02	59.8
		3	20.8037	19.1683	0	-1.0	-.6	40 37 4.53	-41.35	+2	-23	-2	11	23.06	
		4	29.1533	13.2840	+168	-1.6	-1.1	40 29 41.67	+6 41.71	-23	-39	+12	7	22.95	59.9
	5		19.4473	25.2150	+117	-1.0	.0	40 38 48.66	-2 26.14	+8	-16	-5	10	22.49	
		6	28.2360	11.8993	+10	-1.2	-.4	40 29 28.86	+6 53.13	-24	-24	+12	6	21.69	59.8a
		7	11.2867 ⁱⁱ	30.0170 ^{iv}	-6	+.7	-.3	40 28 28.13	+7 53.61	+1.00	+7	+13	5	22.99	59.6
		8	26.8360	12.4320	-47	-2.3	-1.8	40 30 18.91	+6 4.11	-21	-60	+10	6	22.37	
	9		22.6643	18.6537	+23	-.2	.0	40 38 4.52	-1 41.47	+6	-3	-3	11	23.16	59.6
		10	25.9500	15.1663	+51	+1.4	+.8	40 40 30.36	-4 7.53	+14	+32	-7	6	23.28	59.2
Aug. 5	III 1	R	33.7530 ^{iv}	6.7013 ⁱⁱ	+13	-.8	+.5	40 24 57.69	+11 24.08	+88	-6	+20	6	22.85	
		12	13.1020	25.7027	-66	-1.3	-1.1	40 41 41.41	-5 18.46	+19	-35	-10	7	22.76	59.3
		2	29.9237	13.4807	+243	-.5	+1.4	40 43 18.79	-6 56.40	+24	+10	-15	9	22.67	72.5
		3	7.5200 ⁱⁱ	32.5503 ^{iv}	+1	.0	.0	40 46 57.26	-10 32.94	-91	0	-25	11	23.27	71.9
	4	D	6.9917 ⁱⁱ	31.3360 ^{iv}	-33	+2.6	+.7	40 26 5.57	+10 15.50	+92	+50	+18	5	22.72	
		5	33.7027 ^{iv}	9.5860 ⁱⁱ	+59	+1.9	+.5	40 26 11.40	+10 9.98	+92	+37	+19	6	22.92	71.0
		6	13.2980	24.1063	-123	-.6	-1.3	40 31 50.44	+4 33.00	-16	-26	+9	7	23.18	
		7	19.5040	14.9607	-109	+.8	+1.5	40 38 16.99	-1 54.61	+6	+32	-3	6	22.79	
	8		20.7173	23.2473	+43	+.4	+.5	40 37 26.38	-1 4.08	+4	+13	-2	6	22.51	
		8	23.0063	17.3270	+7	+1.4	.0	40 33 59.13	+2 23.63	-9	+22	+4	6	22.99	
Aug. 5	III 1	D	25.1000	10.2850	-297	+1.3	+.6	40 42 36.48	-6 13.87	+22	+28	-10	5	23.06	70.4
		2	11.5720	28.0480	-26	-.2	+.7	40 43 19.04	-6 56.50	+24	+6	-15	9	22.72	75.4
		3	32.8703 ^{iv}	7.8070 ⁱⁱ	+16	+1.6	+2.4	40 46 57.55	-10 33.81	-91	+56	-25	11	23.25	75.5
		4	33.8010 ^{iv}	9.4620 ⁱⁱ	+62	-1.5	-.4	40 26 5.74	+10 15.61	+92	-29	+18	5	22.21	
		R	5.3937 ⁱⁱ	29.5287 ^{iv}	-91	.0	-.1	40 26 11.78	+10 10.07	+92	-1	+19	6	23.01	

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
Aug. 5	III 5	R	26.0707	15.3230	+ 64	— .7	— 1.6	40 31 50.83	+ 4 31.94	— 16	— 31	+ 9	7	40 36 22.46	74.5
	6		18.2700	22.8403	+ 23	+ 1.6	+ 3.3	40 38 17.43	— 1 55.63	+ 6	+ 67	— 3	6	22.56	
Aug. 7	III 1	R	12.2580	27.0543	— 47	— .1	— .2	40 42 36.97	— 6 14.03	+ 22	— 4	— 10	5	23.07	74.4
	2		28.8163	12.3570	+ 81	— .7	+ .8	40 43 19.29	— 6 56.41	+ 24	— 1	— 15	9	23.05	75.5
			4.7937 ⁱⁱ	29.8560 ^{iv}	— 118	— .3	+ .1	40 46 57.82	— 10 33.45	— 91	— 3	— 25	11	23.29	
	3		7.3830 ⁱⁱ	31.6967 ^{iv}	— 18	+ 2.1	+ 1.0	40 26 6.30	+ 10 14.77	+ 92	+ 46	+ 18	5	22.68	
	4		7.7350 ⁱⁱ	31.8370 ^{iv}	— 7	+ .8	+ .4	40 26 12.13	+ 10 9.44	+ 92	+ 18	+ 19	6	22.92	75.4
	5		27.6803	16.9713	+ 220	+ .3	+ 1.0	40 31 51.20	+ 4 31.35	— 16	+ 18	+ 9	7	22.73	75.4
	6		18.3697	22.9150	+ 25	— 1.6	.0	40 38 17.85	— 1 55.00	+ 6	— 25	+ 3	6	22.69	
	7		20.8353	18.2863	— 10	— .3	— .4	40 37 26.91	— 1 4.43	+ 4	— 10	— 2	6	22.46	
	8		17.4147	23.0640	+ 10	— .2	— .3	40 34 0.06	+ 2 22.88	— 9	— 7	+ 4	6	22.88	
	9		13.3140	28.1257	+ 92	— .2	+ .6	40 42 37.43	— 6 14.77	+ 22	+ 4	— 10	5	22.87	74.7
	IV 1	D	19.7253	17.4857	— 27	+ .7	+ .4	40 37 20.00	— 56.56	+ 3	+ 16	— 2	13	23.74	72.4
	2		17.1910	18.9167	— 30	— 1.5	— .9	40 37 6.48	— 43.56	+ 2	— 35	— 2	11	22.68	
	3		11.8960	27.6907	— 27	— .5	— .1	40 29 44.01	+ 6 39.33	— 23	— 9	+ 12	7	23.21	71.4
	4		20.7207	14.8597	— 112	+ .2	— .6	40 38 50.67	— 2 27.92	+ 8	— 4	— 5	10	22.84	
	5		12.4693	28.7410	+ 84	— 1.6	— 1.4	40 29 31.39	+ 6 51.67	— 24	— 43	+ 12	6	22.57	
	6		29.9550 ^{iv}	11.3153 ⁱⁱ	— 6	— 1.4	— .5	40 28 30.37	+ 7 51.32	+ 1.00	— 29	+ 13	5	22.58	70.4
	7		14.4637	28.7243	+ 198	+ 1.8	+ 1.1	40 30 21.14	+ 6 1.10	— 21	+ 43	+ 10	6	22.62	
	9		16.4807	20.5760	— 53	— 1.4	+ 1.8	40 38 6.43	— 1 43.42	+ 6	0	— 3	11	23.15	69.7
Aug. 8	III 1	D	11.4463	27.9533	— 45	+ 1.6	+ 3.1	40 43 19.43	— 6 57.29	+ 24	+ 65	— 15	9	22.97	74.4
	2		33.7603 ^{iv}	8.6987 ⁱⁱ	+ 55	+ .9	+ .9	40 46 57.97	— 10 33.87	— 91	+ 26	— 25	11	23.31	73.6
	3		33.1600 ^{iv}	8.8633 ⁱⁱ	+ 39	— .1	— .1	40 26 6.49	+ 10 14.48	+ 92	— 3	+ 18	5	22.09	
	4		33.8323 ^{iv}	9.7300 ⁱⁱ	+ 64	— .1	— .8	40 26 12.32	+ 10 9.63	+ 92	— 11	+ 19	6	23.01	
	5		13.4863	24.2260	— 108	— .5	+ 1.1	40 31 51.39	+ 4 31.30	— 16	+ 6	+ 9	7	22.75	72.8
	6		21.7827	17.2353	— 20	.0	— .6	40 38 18.06	— 1 54.94	+ 6	— 7	— 3	6	23.14	72.5
	7		18.2730	20.8177	— 10	+ .1	.0	40 37 27.13	— 1 4.32	+ 4	+ 1	— 2	6	22.90	
	8		21.6503	16.0040	— 59	.0	— .1	40 34 0.29	+ 2 22.63	— 9	— 1	+ 4	6	22.92	
Aug. 10	III 1	R	25.1300	10.2870	— 297	.0	— .9	40 42 37.67	— 6 14.58	+ 22	— 14	— 10	5	23.12	71.9
	2		28.9383	12.4570	+ 99	+ .1	+ .2	40 43 19.76	— 6 57.01	+ 24	+ 4	— 15	9	22.97	79.2
	3		6.4233 ⁱⁱ	31.4837 ^{iv}	— 49	— .9	— .6	40 46 58.32	— 10 33.57	— 91	— 22	— 25	11	23.48	78.6
	4		5.6637 ⁱⁱ	30.9437 ^{iv}	— 47	+ 1.0	+ 1.4	40 26 6.91	+ 10 14.21	+ 92	+ 34	+ 18	5	22.61	
	5		27.3627	16.6543	+ 187	— 1.2	— .8	40 31 51.83	+ 4 31.25	— 16	— 29	+ 9	7	22.79	78.4
	6		18.0507	22.6357	+ 14	— .8	+ .1	40 38 18.55	— 1 55.98	+ 6	— 11	— 3	6	22.55	
	7		21.4327	18.8587	— 1	+ .1	— .7	40 37 27.63	— 1 5.09	+ 4	— 7	— 2	6	22.55	78.1
	8		16.2580	21.8897	— 46	— .7	+ 1.2	40 34 0.81	+ 2 22.29	— 9	+ 4	+ 4	6	23.15	
	9		13.1953	28.0190	+ 78	— 1.7	— .2	40 42 38.19	— 6 15.04	+ 22	— 30	— 10	5	23.02	78.0
	IV 1	R	22.0053	24.2823	+ 65	+ .8	+ .1	40 37 20.72	— 57.74	+ 3	+ 14	— 2	13	23.26	75.8
	2		21.4317	19.7007	+ 7	— 2.3	— 1.2	40 37 7.24	— 43.79	+ 2	— 52	— 2	11	23.04	
	3		29.5997	13.8730	+ 240	— .6	— .7	40 29 44.64	+ 6 38.28	— 23	— 18	+ 12	7	22.70	75.3
	4		16.1543	22.0657	— 47	— 1.1	+ .2	40 38 51.94	— 2 29.36	+ 8	— 15	— 5	10	22.06	d
	5		27.0440	10.8070	— 154	.0	— 1.5	40 29 32.24	+ 6 50.19	— 24	— 19	+ 12	6	22.18	
	6		11.1263 ⁱⁱ	29.7127 ^{iv}	— 4	+ 1.5	.0	40 28 31.23	+ 7 49.98	+ 1.00	+ 24	+ 13	5	22.63	74.8
	7		28.0523	13.7860	+ 113	— 1.0	— 1.8	40 30 21.99	+ 6 1.03	— 21	— 39	+ 10	6	22.58	
	8		11.0993	27.8903	— 73	— .6	.0	40 43 27.38	— 7 4.41	+ 24	— 9	— 13	7	23.06	74.5d
	9		21.5877	17.4640	— 19	— .5	— 1.4	40 38 7.13	— 1 44.22	+ 6	— 26	— 3	11	22.79	74.5d
	10		24.8980	14.9930	— 4	+ 1.6	+ .5	40 40 33.31	+ 4 10.46	+ 14	+ 32	— 7	6	23.30	
	11		33.6720 ^{iv}	6.7197 ⁱⁱ	+ 11	— .7	— 1.0	40 25 0.54	+ 11 21.56	+ 88	— 24	+ 20	6	23.00	d
	12		13.1563	25.8540	— 55	— .3	— 1.2	40 41 44.18	— 5 20.94	+ 19	— 20	— 10	7	23.20	74.4
Aug. 12	III 1	D	14.2027	30.6710	+ 350	— .7	— .3	40 43 20.12	— 6 57.31	+ 24	— 15	— 15	9	22.84	77.0
	2		32.8140 ^{iv}	7.7263 ⁱⁱ	+ 12	— 1.5	— .2	40 46 58.70	— 10 34.42	— 91	— 26	— 25	11	22.97	76.8
	3		33.1803 ^{iv}	8.8807 ⁱⁱ	+ 40	— 1.7	— 1.6	40 26 7.38	+ 10 14.56	+ 92	— 48	+ 18	5	22.61	
	4		32.1783 ^{iv}	8.0790 ⁱⁱ	+ 4	— 1.1	— 1.2	40 26 13.22	+ 10 9.40	+ 92	— 33	+ 19	6	23.46	
	5		13.1023	23.8073	— 144	— .1	+ 2.2	40 31 52.32	+ 4 30.33	— 16	+ 26	+ 9	7	22.91	77.0

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
Aug 12	III 6	D	21.9780	17.3827	-14	.1	.6	40 38 19.08	-1 56.16	+ 6	- 9	- 3	6	40 36 22.92	76.6
	7		18.5497	21.1653	- 5	.6	.1	40 37 28.18	-1 6.13	+ 4	- 11	- 2	6	22.02	
	8		21.0697	15.4613	-87	+1.0	+1.0	40 34 1.38	+2 21.60	- 9	+ 29	+ 4	6	23.28	
Aug 13	9		24.7990	9.9007	-344	+1.0	+ 1	40 42 38.77	-6 15.86	+ 22	+ 17	-10	5	23.25	75.6
	IV 1	D	19.4770	17.1497	-39	.7	.8	40 37 21.58	- 58.76	+ 3	- 21	- 2	13	22.75	68.5
	2		20.0347	21.8340	+14	.1	.0	40 37 8.13	- 45.53	+ 2	- 1	- 2	11	22.70	
	3		11.8597	27.5823	-38	+ .3	.9	40 29 45.61	+ 6 37.48	- 23	- 6	+12	7	22.99	
	4		21.5277	15.5817	-77	.8	.5	40 38 52.35	-2 30.16	+ 8	- 19	- 5	10	22.13	68.5
	5		11.9973	28.1790	+14	-1.4	-1.4	40 29 33.25	+ 6 49.22	- 24	- 40	+12	6	22.01	
	6		28.0867 ^{iv}	9.5210 ⁱⁱ	+14	.8	.5	40 28 32.22	+ 7 49.50	+1.00	- 19	+13	5	22.71	68.4
	7		14.8207	29.0080	+236	+1.9	.8	40 30 22.97	+ 5 59.35	- 21	+ 40	+10	6	22.67	
	8		27.2013	10.3590	-181	+1.8	+1.3	40 43 28.32	-7 5.43	+ 24	+ 45	-13	7	23.52	68.0
	9		18.5953	22.7470	+24	.2	.0	40 38 8.01	-1 45.04	+ 6	- 3	- 3	11	23.08	
	10		16.7130	26.6083	+142	-2.2	.1	40 40 34.24	-4 10.58	+ 14	- 37	- 7	6	23.42	67.0
	11		6.1177 ⁱⁱ	33.0333 ^{iv}	-27	.1	+ .1	40 25 1.44	+11 20.54	+ 88	0	+20	6	23.12	66.9
Aug 15	12		25.2137	12.4527	-131	+1.9	.5	40 41 45.05	- 5 22.35	+ 19	+ 37	-10	7	23.23	
	III 1	R	28.4553	11.9600	+30	.3	.3	40 43 20.58	-6 57.19	+ 24	- 9	-15	9	23.48	76.1
	2		6.1167 ⁱⁱ	31.2223 ^{iv}	-62	-1.1	.8	40 46 59.23	-10 34.68	- 91	- 27	-25	11	23.23	75.4
	3		7.7103 ^{iv}	31.9610 ^{iv}	- 6	+ .7	+ .2	40 26 8.02	+10 13.41	+ 92	+ 13	+18	5	22.71	
	4		3.6330 ⁱⁱ	27.6930 ^{iv}	-157	.8	.6	40 26 13.88	+10 8.00	+ 92	- 20	+19	6	22.85	74.4
	5		25.8967	15.2267	+51	-1.7	.5	40 31 53.01	+ 4 29.94	- 16	- 34	+ 9	7	22.61	
	6		18.5977	23.2103	+36	-1.3	.5	40 38 19.84	-1 56.73	+ 6	- 27	- 3	6	22.93	
	7		20.5060	17.8647	-18	.8	.7	40 37 28.99	-1 6.74	+ 4	- 14	- 2	6	22.19	
	8		15.8290	21.3927	-69	.8	.0	40 34 2.21	+2 20.51	- 9	- 13	+ 4	6	22.60	
	9		12.1867	27.0753	-49	-2.0	.6	40 42 39.63	-6 16.36	+ 22	- 39	-10	5	23.05	74.5
	IV 1	R	18.0510	20.3873	-14	.8	.8	40 37 22.18	- 59.04	+ 3	- 23	- 2	13	23.05	72.4
	2		22.5847	20.7913	+27	-2.0	-1.4	40 37 8.76	- 45.43	+ 2	- 50	- 2	11	22.94	
	3		28.4610	12.8153	+86	.1	.9	40 29 46.30	+ 6 35.85	- 23	+ 10	+12	7	22.21	
	4		18.2380	24.2023	+64	+ .5	+2.5	40 38 53.00	-2 30.98	+ 8	+ 40	- 5	10	22.55	71.6
	5		29.9307	13.7960	+261	.2	.1	40 29 33.96	+ 6 48.65	- 24	+ 4	+12	6	22.59	
	6		10.8867 ⁱⁱ	29.3997 ^{iv}	- 2	+2.2	+2.3	40 28 32.94	+ 7 48.13	+1.00	+ 65	+13	5	22.90	71.3
	7		27.7677	13.5973	+83	.8	.2	40 30 23.69	+ 5 58.53	- 21	- 15	+10	6	22.02	
	9		20.8853	16.7020	-45	+ .9	+ .7	40 38 8.59	-1 45.67	+ 6	+ 23	- 3	11	23.29	71.4
	10		24.8310	14.8570	-13	+1.3	.2	40 40 34.92	-4 12.18	+ 14	+ 23	- 7	6	23.10	
	11		35.6133 ^{iv}	8.7593 ⁱⁱ	+130	.8	.1	40 25 2.09	+11 19.38	+ 88	- 14	+20	6	22.47	
Aug 18	12		12.7653	25.5480	-94	.5	.7	40 41 45.69	- 5 23.00	+ 19	- 17	-10	7	22.68	71.4
	III 1	D	11.9913 ⁱⁱ	28.4920 ^{iv}	- 7	+1.4	+1.3	40 43 20.86	-6 57.23	-1.04	+ 39	-15	9	22.92	71.4
	2		31.8417 ^{iv}	6.7007 ⁱⁱ	-34	.2	+ .1	40 46 59.57	-10 35.65	- 91	- 1	-25	11	22.86	
	3		33.6667 ^{iv}	9.4270 ⁱⁱ	+59	-1.9	-1.5	40 26 8.49	+10 13.09	+ 92	- 49	+18	5	22.24	
	4		33.3410 ^{iv}	9.3047 ⁱⁱ	+47	-1.2	-1.3	40 26 14.35	+10 7.92	+ 92	- 36	+19	6	23.08	
	5		13.7880	24.4433	-81	.2	.1	40 31 53.52	+ 4 29.23	- 16	+ 1	+ 9	7	22.76	70.4
	6		22.5067	17.8500	+ 8	+ .9	.0	40 38 20.44	-1 57.77	+ 6	+ 14	- 3	6	22.90	
	7		19.0150	21.6850	+ 8	+1.4	+1.8	40 37 29.62	-1 7.54	+ 4	+ 45	- 2	6	22.61	70.4
	8		22.9807	17.4383	+ 9	.4	.7	40 34 2.88	+2 20.17	- 9	- 15	+ 4	6	22.91	70.4
	9		26.2887	11.3727	-150	-1.5	-1.9	40 42 40.33	-6 16.80	+ 22	- 48	-10	5	23.22	69.5
	IV 1	D	20.2373	17.8823	-18	-2.5	-2.7	40 37 22.99	- 59.50	+ 3	- 74	- 2	13	22.89	68.4
	2		19.2723	21.1053	+ 1	-2.7	-1.0	40 37 9.61	- 46.35	+ 2	- 56	- 2	11	22.81	
	3		11.6557	27.3177	-67	+ .5	+ .5	40 29 47.24	+ 6 35.86	- 23	+ 14	+12	7	23.20	68.5
	4		22.2330	16.2140	-43	+1.4	+ .1	40 38 53.89	-2 32.09	+ 8	+ 24	- 5	10	22.17	
	5		12.0270	28.1423	+11	.0	.4	40 29 34.93	+ 6 47.53	- 24	- 5	+12	6	22.35	67.5
Aug 19	III 2	R	7.2353 ⁱⁱ	32.3397 ^{iv}	-10	.1	-1.1	40 46 59.66	-10 34.78	- 91	- 15	-25	11	23.68	65.4
	3		7.2517 ⁱⁱ	31.4773 ^{iv}	-24	+2.3	+1.4	40 26 8.62	+10 12.53	+ 92	+ 55	+18	5	22.85	
	4		7.7633 ⁱⁱ	31.7823 ^{iv}	- 8	-1.0	.0	40 26 14.49	+10 7.34	+ 92	- 16	+19	6	22.84	
	5		27.4970	16.8803	+202	+ .4	.1	40 31 53.66	+ 4 28.97	- 16	+ 5	+ 9	7	22.68	65.9
	6		18.7563	23.4127	+45	-1.1	.4	40 38 20.61	-1 57.86	+ 6	- 22	- 3	6	22.62	

1895.	Star.	P	Micrometer.		C	Levels.		$\frac{1}{2}(\delta + \delta')$	Corrections.					Latitude.	Thermom.
						A	B		Micrometer.	δ	l	r	Mer		
Aug 19	III 7	R	19.2623	16.6047	-49	+1.2	-.4	40 37 29.79	-1 7.08	+ 4	+ 14	- 2	6	40 36 22.93	64.8
	8		18.3123	23.8263	+51	-.6	-.1	40 34 3.08	+ 2 19.56	- 9	- 11	+ 4	6	22.54	64.8
	9		13.8397	28.7437	+168	-1.2	-1.2	40 42 40.53	- 6 17.30	+ 22	- 35	-10	5	23.05	65.0
	IV 1	R	19.5483	21.9500	+15	+2.1	+.7	40 37 23.23	- 1 0.77	+ 3	+ 43	- 2	13	23.03	62.0
	2		22.3017	20.4440	+21	-.1	+.7	40 37 9.86	- 47.03	+ 2	+ 7	- 2	11	23.01	
	3		29.1583	13.5593	+184	-.0	-.5	40 29 47.52	+ 6 34.91	- 23	- 6	+12	7	22.33	61.5
	4		18.8640	24.8460	+98	-1.3	-.5	40 38 54.16	- 2 31.51	+ 8	- 27	- 5	10	22.51	
	5		28.2740	12.1780	+24	-.3	+.1	40 29 35.25	+ 6 47.10	- 24	- 3	+12	6	22.26	
	6	D	29.4143 ^{iv}	10.9210 ⁱⁱ	- 2	-1.1	-1.0	40 28 34.25	+ 7 47.63	+1.00	- 30	+13	5	22.76	62.1
	7		13.8157	27.9407	+108	+.9	-.3	40 30 25.00	+ 5 57.45	- 21	+ 10	+10	6	22.50	
	8		33.7157	16.8823	+771	+1.4	+.5	40 43 30.29	- 7 7.61	+ 24	+ 29	-13	7	23.15	
	9		14.8993	19.1410	-109	-.4	+1.7	40 38 9.74	- 1 46.98	+ 6	+ 16	- 3	11	23.06	
	10		15.5310	25.5287	+43	-.8	+.2	40 40 36.23	- 4 12.92	+ 14	- 10	- 7	6	23.34	59.8
	11		5.6850 ⁱⁱ	32.4977 ^{iv}	-55	+1.0	+.3	40 25 3.38	+11 17.87	+ 88	+ 20	+20	6	22.59	59.3

Adjustment of the Latitude.

In case every pair of a given group has been observed on any night, the mean of the resulting latitudes will be based upon the mean value of the declinations of all stars of this group. The differences between the individual values and the mean of all will furnish the corrections required to reduce the individual latitudes to the mean system. These corrections will only be required in case of failure to observe one or more of the pairs forming the group.

In order to avoid errors resulting from outstanding uncertainties as to the value of the micrometer screw, it is desirable that the plus and minus corrections of each group shall balance as nearly as may be. This condition cannot be fully realized, at least not for any considerable time, owing to the effect of precession. The following tabular statement gives the approximate values of these corrections, in terms of micrometer revolutions, for each group of this series.

		Beginning.				End.			
		I	II	III	IV	I	II	III	IV
Pair	1	-15.3	- 6.4	-15.8	- 1.3	-15.4	- 6.4	-16.4	- 2.1
	2	+ 4.2	- 5.1	-24.4	- 0.7	+ 4.0	- 5.1	-25.0	- 1.6
	3	-14.2	+ 2.5	+25.2	[+16.8]	-14.4	+ 2.5	+24.4	[+15.9]
	4	- 3.5	- 2.1	+25.0	- 4.8	- 3.6	- 2.1	+24.2	- 5.7
	5	+ 8.3	- 0.3	+11.7	+17.4	+ 8.3	- 0.3	+10.9	+16.4
	6	+ 6.7	-22.9	- 3.5	+19.8	+ 6.8	-22.9	- 4.4	+18.8
	7	-16.1	[-11.7]	- 1.4	+15.4	-16.1	[-11.7]	- 2.4	+14.4
	8	+ 6.4	+20.9	+ 6.8	-15.6	+ 6.5	+20.8	+ 5.8	-16.6
	9	- 5.3	[+ 3.5]	-13.6	- 3.0	- 5.2	[+ 3.5]	-14.7	- 4.0
	10	+21.4	+16.0		- 8.7	+21.6	+15.9		- 9.8
	11				[+28.1]				[+27.1]
	12				-11.5				-12.6
Mean . . .		-0.7	- 0.6	+ 1.1	+ 4.3	- 0.7	- 1.0	+ 0.3	+ 3.3
Omitting brackets			+ 0.3		+ 0.4		+ .3		- 0.1

By omitting the bracketed pairs in Groups II and IV the algebraic sum of the corrections is in every case so small that very little apprehension need exist with respect to errors from this source. The latitudes have therefore been reduced to the means of the remaining pairs of these groups. One of the component stars of Pair 9, Group II, is a variable which was lost on so many occasions that this pair was not included.

The following tabular statements show the individual differences from the mean values, with the resulting reductions for the separate pairs.

I.

1894.	1	2	3	4	5	6	7	8	9	10
Jan. 19	+ 3	+ 59	- 56	- 5	- 58	+ 22	- 55	+ 31	+ 52	+ 02
25	- 3	+ 19	+ 3	- 71	+ 3	+ 29	- 16	- 19	+ 35	+ 24
27	+ 9	+ 13	- 21	+ 16	- 28	+ 2	- 44	+ 19	- 6	+ 35
30	- 2	+ 42	- 7	+ 2	+ 47	+ 17	- 12	- 24	- 8	- 51
Feb. 6	+ 25	+ 1.15	+ 5	- 63	+ 4	- 89	- 29	- 8	+ 43	+ 3
23	+ 19	+ 38	- 11	+ 6	+ 63	- 49	- 31	+ 9	- 26	- 19
24	- 4	+ 8	+ 23	- 24	- 70	- 18	- 8	+ 38	+ 23	+ 36
27	- 46	+ 60	+ 19	- 31	- 12	+ 10	- 24	+ 15	+ 19	- 9
Mar. 3	- 16	+ 41	- 65	- 25	+ 12	- 7	- 17	+ 9	+ 25	+ 47
4	+ 16	+ 70	- 12	- 14	+ 29	- 52	+ 15	- 28	- 11	- 13
7	+ 38	+ 31	+ 9	- 42	- 49	- 8	- 25	- 26	+ 31	+ 39
12	+ 20	+ 17	- 21	- 18	+ 14	- 30	- 20	+ 19	+ 29	- 10
14	+ 13	+ 21	- 7	- 39	+ 38	- 9	- 33	- 13	+ 21	- 11
Oct. 11	- 44	+ 11	+ 78	+ 91	- 16	- 61	- 13	- 39	+ 6	- 10
17	- 28	+ 30	+ 8	- 22	- 14	- 13	+ 9	- 38	+ 15	+ 48
18	+ 12	+ 30	+ 13	+ 42	- 58	- 27	- 7	+ 12	+ 39	- 52
19	+ 11	+ 52	+ 29	- 47	+ 22	- 52	+ 33	- 86	+ 58	- 24
27	+ 30	+ 65	- 40	+ 19	- 26	- 27	- 18	- 11	+ 40	- 38
31	- 19	+ 14	+ 23	- 33	- 30	+ 16	- 32	- 44	+ 79	+ 26
Nov. 1	- 30	+ 50	- 25	+ 1	- 42	+ 11	- 25	- 3	+ 65	+ 3
3	- 13	+ 12	+ 29	- 13	- 5	- 6	- 46	- 12	+ 35	+ 18
10	- 0	- 12	+ 27	- 34	+ 29	- 24	- 46	+ 36	+ 17	+ 2
11	- 14	+ 32	- 8	- 11	- 52	+ 4	- 5	- 22	+ 34	+ 40
19	- 2	+ 31	+ 5	- 16	+ 5	- 35	- 10	- 54	+ 40	+ 40
Dec. 3	- 16	+ 54	- 22	+ 12	- 54	+ 23	- 56	+ 6	+ 48	+ 3
4	- 16	+ 17	+ 56	- 44	+ 13	- 13	- 24	- 44	+ 76	- 17
5	+ 19	+ 35	- 8	+ 34	- 32	- 16	- 53	+ 20	+ 21	- 19
23	- 2	+ 38	- 13	+ 6	+ 6	+ 7	- 87	+ 12	+ 86	- 52
27	+ 41	- 17	- 13	- 56	+ 43	+ 21	+ 14	- 70	- 21	+ 62
1895. 31	+ 4	- 32	+ 51	- 54	+ 2	- 26	- 34	+ 16	+ 60	+ 12
Jan. 1	+ 29	+ 1.06	- 1	- 48	- 89	- 34	- 92	+ 32	+ 89	+ 8
4	+ 11	+ 43	+ 4	- 32	- 79	- 93	- 38	+ 47	+ 1.04	+ 32
11	+ 13	+ 6	- 16	+ 15	- 23	- 9	+ 8	- 9	+ 18	- 1
16	- 7	+ 21	+ 23	+ 37	- 50	- 31	- 60	+ 38	+ 4	+ 21
19	+ 18	+ 42	+ 45	- 6	+ 11	- 58	+ 16	- 21	- 47	+ 4
23	+ 22	- 16	- 51	+ 32	- 27	- 13	- 52	+ 53	+ 30	+ 18
24	- 42	+ 14	+ 17	- 32	+ 18	- 27	- 32	- 13	+ 59	+ 37
27	+ 55	+ 4	- 3	- 56	- 5	- 25	- 41	+ 62	+ 8	+ 3
31	+ 5	+ 28	+ 7	- 60	- 11	- 18	- 28	+ 16	+ 54	+ 7
Feb. 2	+ 7	- 12	- 8	- 10	- 26	- 1	- 28	- 23	+ 92	+ 9
Mar. 3	+ 10	+ 13	+ 81	- 75	+ 4	- 45	- 23	- 18	+ 5	+ 45
9	+ 16	+ 58	- 41	+ 11	- 23	- 1	- 64	+ 18	- 30	+ 57
Mean .	+ 03	+ 30	+ 02	- 16	- 13	- 17	- 27	- 03	+ 32	+ 09

II.

1894.	1	2	3	4	5	6	7	8	9	10
Feb. 1	+ 14	— 20	+ 3	+ 13	— 18	+ 34	— 28	— 41		+ 15
16	— 38	+ 68	+ 15	— 57	— 6	+ 22	+ 31	— 2		+ 1
24	+ 6	+ 77	+ 7	— 7	+ 45	— 38	— 20	— 69		— 23
26	— 13	— 24	+ 6	— 98	— 37	— 28	— 22	+ 37		— 37
Mar. 4	— 22	+ 35	+ 4	+ 49	+ 12	— 15	+ 60	— 46		— 14
14	— 36	+ 33	— 4	+ 49	+ 14	— 6	+ 74	— 29	— 18	— 17
16	— 24	— 59	+ 30	+ 31	— 12	+ 32	+ 04	— 25	— 46	+ 12
April 13	— 29	— 39	+ 3	+ 26	+ 18	+ 1	— 22	— 3	— 14	+ 19
14	— 19	— 3	+ 28	+ 42	— 17	— 97	+ 69	+ 25	— 53	+ 10
15	+ 15	— 35	— 11	+ 63	— 7	— 45	— 13	+ 26	— 15	— 6
22	+ 2	— 20	+ 40	+ 59	+ 29	— 69	+ 31	— 53	+ 8	+ 9
24	+ 8	— 20	— 14	+ 26	— 3	— 6	— 41	+ 13	— 4	— 7
25	— 29	— 36	+ 52	+ 61	+ 76	— 53	+ 76	— 56	— 28	— 13
26	— 32	+ 26	— 24	+ 42	+ 13	+ 9	+ 4	— 44	— 2	+ 10
May 8	— 40	+ 26	— 0	+ 43	+ 20	— 52	+ 44	— 21	— 39	+ 21
9	— 2	— 70	+ 27	+ 57	+ 27	+ 39	+ 12	— 61	— 62	+ 20
12	+ 4	— 19	+ 11	+ 61	+ 22	— 72	— 16	— 28	— 24	+ 18
26	— 16	— 12	+ 23	+ 38	— 8	— 23	+ 23	— 25	— 33	+ 26
June 10	— 32	— 8	+ 3	+ 42	+ 46	— 5	— 8	— 58	— 96	+ 18
14	— 11	+ 13	+ 12	+ 36	+ 54	— 64	+ 46	— 16		— 26
15	— 24	+ 16	+ 15	+ 97	+ 16	— 15	— 3	— 85	— 30	— 17
17	+ 10	— 5	— 3	+ 43	+ 33	— 24	+ 38	— 1		— 51
1895. 22	+ 30	— 35	— 17	+ 21	+ 68	— 27	+ 13	— 59		+ 17
Mar. 16	+ 59	— 17	— 21	+ 14	— 10	— 45	+ 33	— 3	— 12	+ 20
17	— 20	— 39	+ 34	+ 20	+ 68	— 7	+ 60	— 57	— 51	+ 2
21	+ 24	— 32	— 9	+ 39	+ 17	+ 3	+ 6	— 22	— 30	+ 19
25	— 10	+ 19	+ 32	— 21	— 6	— 20	+ 29	— 38	— 52	+ 42
28	— 2	— 4	— 10	+ 64	+ 32	— 23	— 30	— 33	— 77	— 22
April 10	+ 27	— 28	+ 18	+ 37	+ 7	— 48	+ 17	— 11	— 8	— 2
11	— 1	— 57	+ 16	+ 44	+ 31	— 14	— 33	+ 16	— 27	— 3
14	— 25	— 3	+ 13	+ 5	+ 43	— 31	— 11	— 35	— 74	+ 35
18	— 0	— 30	— 26	+ 85	— 30	— 50	+ 9	— 22	— 7	+ 69
19	— 2	+ 46	— 58	+ 22	— 11	+ 11	+ 37	— 33	— 32	+ 26
20	— 1	+ 11	— 40	+ 14	— 37	— 12	+ 51	+ 34	— 42	+ 28
21	+ 15	— 16	— 12	+ 29	+ 7	— 55	+ 1.03	— 13	— 15	+ 41
23	+ 8	— 7	— 19	+ 72	+ 7	— 59	— 29	— 51	— 85	+ 47
May 1	— 41	+ 43	+ 13	+ 69	— 10	— 41	— 8	— 19	— 49	+ 20
6	— 46	+ 12	— 5	+ 49	+ 49	— 37	+ 82	— 33	— 45	+ 9
9	+ 11	— 25	— 5	+ 52	+ 85	— 17	+ 31	— 51	— 59	— 4
16	— 88	+ 82	— 36	+ 65	+ 28	— 40	+ 6	— 52	— 29	+ 38
18	+ 7	— 23	— 3	+ 29	+ 31	— 24	+ 59	— 43	— 44	+ 27
22	— 43	— 20	+ 48	+ 24	— 13	— 3	— 23	— 5	— 77	+ 13
23	+ 36	— 44	— 25	+ 22	+ 45	— 18	+ 39	— 30	— 8	+ 13
28	+ 17	— 14	— 25	+ 15	+ 42	— 24	— 17	— 30	— 82	+ 21
29	+ 19	— 33	+ 14	+ 25	+ 49	— 38	+ 3	— 4	— 69	+ 30
30	— 48	— 4	— 19	+ 29	+ 59	— 22	— 10	— 6	— 65	+ 13
June 7	— 41	+ 8	+ 39	+ 33	+ 41	— 22	+ 60	— 38	— 29	— 18
8	— 22	— 5	+ 8	+ 48	+ 40	+ 2	+ 18	— 62	— 90	— 8
9	+ 6	— 37	— 9	+ 58	+ 1	— 19	+ 26	— 62	+ 12	+ 63
11	— 20	+ 22	— 1	— 4	+ 35	— 17	+ 27	— 51	— 52	+ 32
14	+ 28	+ 5	+ 23	+ 31	+ 20	— 40	+ 41	— 52		+ 18
23	— 14	— 2	+ 9	+ 30	— 0	— 20	+ 31	+ 8	— 66	— 14
Mean .	— 09	— 06	+ 02	+ 37	+ 20	— 24	+ 18	— 27	— 40	+ 07

III.

1894.	1	2	3	4	5	6	7	8	9
May 8	— 4	— 22	— 41	— 32	+ 37	+ 37	+ 33	— 24	+ 19
12	— 0	— 35	+ 24	— 11	+ 13	— 17	+ 58	+ 29	— 63
26	— 10	— 50	— 13	— 40	+ 26	+ 22	+ 23	+ 74	— 32
27	— 11	— 33	+ 61	— 85	+ 7	— 10	+ 66	+ 51	— 47
June 10	+ 12	— 48	— 8	— 50	+ 2	+ 12	+ 22	+ 42	+ 18
15	— 15	— 35	— 5	— 87	+ 63	— 9	— 1	+ 37	+ 49
28	— 3	— 11	— 16	— 22	+ 25	— 0	+ 11	+ 21	— 3
July 9	+ 26	+ 19	+ 3	— 53	— 4	— 0	+ 22	+ 18	— 27
12	— 2	— 24	— 42	— 31	+ 39	+ 26	+ 30	— 14	+ 14
13	— 37	+ 3	+ 6	— 93	+ 26	+ 9	+ 20	+ 87	— 24
17	— 22	— 32	— 0	— 33	+ 48	+ 22	+ 12	— 16	+ 17
25	— 8	— 62	+ 47	— 12	+ 18	+ 5	— 22	+ 61	— 24
Aug. 5	+ 65	— 51	— 25	— 31	— 9	+ 20	+ 10	— 3	+ 26
6	+ 24	+ 4	— 64	— 49	+ 2	+ 18	+ 43	— 12	+ 32
9	+ 51	+ 7	— 24	— 97	+ 30	+ 35	+ 25	— 19	— 9
10	+ 14	+ 45	— 73	— 85	+ 21	+ 27	+ 27	+ 6	+ 16
21	+ 31	+ 41	— 80	— 12	+ 1	+ 7	— 33	+ 13	+ 30
22	— 2	+ 59	+ 25	— 1.04	— 5	+ 15	+ 32	— 5	— 16
23	+ 28	— 20	— 48	— 82	+ 35	+ 54	+ 25	— 31	+ 40
24	+ 44	+ 18	+ 21	— 79	— 39	+ 6	+ 45	— 20	+ 7
31	+ 26	— 1	— 29	— 35	+ 17	+ 3	— 4	— 4	+ 24
Sept. 11	— 1	+ 34	— 49	— 70	+ 2	— 0	+ 28	+ 27	+ 30
Mean .	+ 09	— 09	— 15	— 54	+ 16	+ 13	+ 21	+ 15	+ 04

III.

1895.	1	2	3	4	5	6	7	8	9
May 9	— 5	— 57	+ 19	— 45	+ 28	— 16	+ 23	+ 36	+ 20
10	— 10	— 35	+ 35	— 60	+ 5	+ 32	+ 34	+ 52	— 42
22	— 9	— 22	— 8	— 68	+ 9	+ 40	+ 51	— 17	+ 20
23	+ 20	— 29	+ 61	— 21	+ 8	+ 2	— 3	— 28	— 11
28	— 22	— 43	— 14	— 52	+ 28	+ 11	+ 34	+ 68	— 8
29	— 31	— 38	+ 43	— 51	— 6	+ 25	+ 41	+ 29	— 15
30	— 40	— 36	— 11	— 13	— 7	+ 23	+ 58	+ 24	— 24
June 7	+ 14	— 18	+ 51	— 19	+ 25	— 40	+ 51	— 29	— 37
8	— 26	— 34	— 7	— 55	+ 4	+ 49	+ 28	+ 69	— 30
11	— 31	— 16	— 34	— 46	+ 40	+ 59	+ 32	+ 42	— 49
25	+ 15	— 10	+ 54	— 78	— 27	+ 14	+ 84	— 11	— 38
July 9	— 54	— 23	+ 56	— 17	— 2	— 28	+ 46	+ 7	+ 16
10	— 42	— 39	— 6	— 1	+ 29	— 17	+ 77	+ 29	— 32
12	— 7	— 33	+ 42	— 9	— 30	— 5	+ 30	+ 33	— 19
18	— 21	— 8	+ 71	— 10	— 2	— 50	+ 29	+ 23	— 28
19	+ 26	— 22	— 2	— 80	+ 33	+ 8	+ 27	+ 16	— 4
25	— 5	+ 33	+ 49	— 51	+ 12	— 18	+ 25	— 7	— 37
28	— 21	— 36	+ 71	— 30	— 11	— 28	+ 44	+ 39	— 27
30	+ 8	— 50	+ 26	— 29	+ 12	— 2	+ 17	+ 3	+ 15
31	+ 6	— 15	+ 44	— 32	+ 50	— 8	— 4	— 12	— 30
Aug. 3	+ 23	— 37	+ 18	— 2	— 28	+ 11	+ 39	— 9	— 16
7	— 21	— 45	+ 16	— 8	+ 11	+ 15	+ 38	— 4	— 3
8	— 6	— 40	+ 82	— 10	+ 16	— 23	+ 1	— 1	— 21
10	— 8	— 59	+ 23	— 4	+ 10	+ 34	+ 34	— 26	— 13
12	+ 8	— 5	+ 31	— 54	+ 1	— 0	+ 90	— 36	— 33
15	— 63	— 38	+ 14	— 0	+ 24	— 8	+ 66	+ 25	— 20
18	— 9	— 3	+ 59	— 25	+ 7	— 7	+ 22	— 8	— 39
Mean .	— 11	— 28	+ 30	— 32	+ 9	+ 3	+ 37	+ 11	— 19

IV.

1894.	1	2	3	4	5	6	7	8	9	10	11	12
July 9	— 12	— 11	+ 9	+ 34	— 35	— 34	+ 30	— 38	+ 51	— 34	— 52	+ 50
12	+ 32	— 5	+ 37	+ 77	+ 5	— 70	+ 64	— 32	— 19	— 30	+ 42	— 22
18	— 19	+ 50	— 16	+ 24	+ 11	— 19	+ 12	— 31	— 12	— 24	— 51	+ 8
Aug. 5	— 37	+ 5	— 28	+ 49	— 19	— 1	+ 9	— 32	— 25	— 8	— 76	+ 50
6	— 14	— 8	— 18	+ 31	+ 23	— 53	— 3	— 50	— 8	+ 22	— 61	+ 58
9	— 80	+ 41	— 37	+ 41	+ 2	— 14	+ 18	— 30	+ 7	— 4	— 45	+ 21
20	— 14	+ 26	— 50	+ 26	— 34	— 37	— 8	— 49	— 33	+ 58	— 1.12	+ 63
22	— 2	— 12	— 3	+ 57	+ 3	— 36	+ 18	— 31	+ 11	+ 9	— 38	+ 19
23	+ 36	— 0	— 40	+ 11	+ 8	— 27	+ 16	— 47	+ 15	— 40	—	+ 31
31	— 46	— 4	— 25	+ 6	+ 53	+ 22	— 18	— 47	— 8	— 10	— 69	+ 57
Sept. 11	— 27	+ 12	— 22	+ 56	+ 12	+ 15	+ 29	— 99	— 1	— 24	— 22	+ 23
12	+ 3	+ 41	— 3	+ 29	+ 12	— 21	+ 18	— 76	+ 7	— 2	— 39	— 8
15	— 8	+ 5	— 5	+ 23	— 31	— 26	+ 55	— 56	— 31	+ 1	— 16	+ 11
Oct. 5	+ 12	+ 1	+ 4	+ 67	+ 28	— 22	+ 27	— 12	— 14	— 58	— 23	— 26
6	+ 9	+ 18	— 74	+ 9	— 42	— 20	— 11	— 39	+ 27	+ 18	— 78	+ 28
16	— 31	+ 3	+ 30	+ 98	+ 46	— 46	+ 21	— 16	— 66	+ 13	— 30	— 25
18	— 25	— 32	— 8	+ 65	+ 16	— 67	+ 22	— 36	+ 15	+ 1	— 78	+ 43
19	— 9	+ 31	— 27	+ 53	— 15	+ 32	— 18	— 79	+ 12	— 31	— 54	+ 26
20	— 54	+ 3	+ 3	+ 52	— 6	— 37	+ 6	+ 30	— 21	— 14	— 24	+ 24
Nov. 1	+ 8	+ 47	— 9	+ 39	+ 13	— 26	+ 3	— 41	— 10	— 37	— 16	+ 8
4	— 32	— 5	+ 30	+ 1.02	+ 4	— 20	+ 10	— 26	— 49	— 36	— 32	+ 56
11	— 11	+ 16	— 20	+ 19	— 0	+ 3	+ 14	— 48	+ 5	— 26	— 37	+ 30
12	+ 11	+ 28	+ 38	+ 74	— 6	— 71	+ 53	— 22	— 45	— 54	+ 47	+ 21
15	— 17	— 25	— 48	+ 42	+ 3	+ 12	+ 1	— 35	— 1	+ 1	— 65	+ 24
19	— 12	+ 10	— 72	+ 3	+ 16	— 12	— 25	— 5	— 27	+ 60	— 17	— 3
20	— 23	+ 5	+ 33	+ 1.05	— 8	— 25	+ 40	— 29	+ 4	— 58	— 11	— 10
21	— 66	+ 44	— 35	+ 67	— 8	+ 7	+ 14	— 65	— 25	+ 10	— 16	+ 22
22	— 50	— 3	—	+ 28	+ 17	— 30	+ 26	— 6	+ 6	— 29	— 62	+ 37
26	— 31	— 6	— 54	+ 45	+ 13	— 0	+ 6	— 29	+ 3	— 4	— 59	+ 3
27	+ 13	— 16	— 20	+ 66	+ 33	— 1	+ 43	— 3	— 1.13	+ 2	— 66	— 33
29	+ 50	— 26	— 16	+ 45	+ 16	— 1	— 4	— 34	— 33	— 44	— 14	+ 29
Mean .	— 14	+ 07	— 15	+ 46	+ 07		+ 15	— 36	— 13	— 12	— 39	+ 20

IV.

1895.	1	2	3	4	5	6	7	8	9	10	11	12
July 16	— 16	— 45	— 73	+ 47	— 4	+ 32	+ 13	— 81	— 8	+ 2	— 18	+ 57
18	— 44	— 1	+ 33	+ 78	+ 27	— 15	+ 63	— 74	+ 6	— 31	— 25	— 5
19	— 72	+ 64	— 66	+ 39	+ 33	— 9	+ 14	— 58	— 24	+ 14	— 31	— 1
28	+ 28	— 24	+ 34	+ 33	+ 34	— 8	+ 96	— 66	— 12	— 41	+ 13	— 44
29	+ 35	+ 1	— 6	+ 26	+ 47	— 7	+ 13	— 39	— 18	+ 20	+ 50	— 81
Aug. 10	— 45	— 23	+ 11	+ 75	+ 63	+ 18	+ 23	— 25	+ 3	— 49	— 19	— 39
13	+ 17	+ 22	— 7	— 21	+ 91	+ 21	+ 25	+ 60	— 16	— 50	— 20	— 31
Mean .	— 14	— 01	— 10	+ 40	+ 42	+ 5	+ 35	— 57	— 10	— 19	— 07	— 21

In the following tabular statement the column headed ϕ_1 gives the daily mean value of the seconds of latitude, the preceding corrections being applied when necessary. In column ϕ_2 the corrections for aberration and final adjustment of groups derived on pages 149 and 151 have been applied.

	I			II			III				II			III			IV			I		
	ϕ_1	ϕ_2	No	ϕ_1	ϕ_2	No	ϕ_1	ϕ_2	No		ϕ_1	ϕ_2	No	ϕ_1	ϕ_2	No	ϕ_1	ϕ_2	No	ϕ_1	ϕ_2	No
1894	"	"		"	"		"	"		1894	"	"		"	"		"	"		"	"	
Jan. 19	23.34	23.23	10							June 22	22.82	22.92	9	22.94	22.92	7						
25	22.79	22.67	10							27	22.86	22.97	8									
27	23.28	23.17	10	23.09	23.08	8				28	22.96	23.07	8	22.93	22.92	9						
28	23.34	23.22	7							July 3	22.78	22.89	7	22.93	22.92	8						
30	22.92	22.81	10							5	22.79	22.91	7	22.79	22.80	4						
31	23.38	23.26	9							9				23.11	23.11	9	22.88	22.91	12			
Feb. 1				23.35	23.34	9				10				22.68	22.70	5						
4				22.81	22.79	3				11				23.32	23.33	1						
5	23.30	23.20	9							12				22.81	22.82	9	22.95	23.00	12			
6	23.23	23.12	10							13				22.96	22.97	9	22.93	22.97	12			
11	23.17	23.06	9	23.07	23.06	2				17				22.96	22.98	9	22.86	22.92	4			
15	23.14	23.08	9							24				23.16	23.19	8	23.11	23.16	11			
16	23.28	23.18	7	23.35	23.34	9				25				23.23	23.26	9	23.01	23.08	11			
19	23.10	23.00	3							Aug. 5				22.92	22.95	9	23.04	23.10	12			
20	22.91	22.80	3							6				22.68	22.72	9	22.75	22.82	12			
23	23.05	22.95	10	22.95	22.94	8				9				22.93	22.97	9	22.60	22.67	12			
24	22.95	22.84	10	23.13	23.12	9				10				23.01	23.05	9	22.75	22.83	11			
26				23.35	23.34	9				20				22.95	23.00	7	22.77	22.85	12			
27	23.57	23.47	10							21				22.87	22.92	9						
Mar. 3	23.42	23.31	10	23.41	23.40	8				22				23.04	23.09	9	22.90	22.99	12			
4	23.32	23.22	10	23.27	23.26	9				23				22.96	23.01	9	22.84	22.92	11			
7	23.55	23.44	10							24				22.97	23.02	9	22.92	23.01	11			
8	23.20	23.09	7	23.20	23.19	3				31				22.92	22.98	9	22.92	23.01	12			
12	23.36	23.26	10							Sept. 7				22.91	22.97	8						
13				23.13	23.12	5				11				22.89	22.95	9	23.00	23.11	12			
14	23.25	23.14	10	23.20	23.19	10				12				22.99	23.06	8	22.85	22.95	12			
16	23.10	23.00	8	23.14	23.14	10				15				22.79	22.86	8	22.97	23.06	12			
17	23.31	23.20	8	23.38	23.38	3				Oct. 2							23.00	23.12	11			
18	23.22	23.12	8							5							22.99	23.12	12			
19				23.11	23.10	9				6							23.07	23.20	12	23.33	23.18	8
Apl. 6				23.56	23.58	1				11							23.16	23.30	5	23.16	23.00	10
7				22.99	23.00	9				15							23.04	23.17	11			
13				23.37	23.39	10				16							22.90	23.04	12	23.23	23.08	9
14				23.22	23.24	10				17							23.02	23.15	11	23.32	23.17	10
15				23.07	23.09	10				18							22.91	23.05	12	23.31	23.16	10
16				23.18	23.21	2				19							23.12	23.25	12	23.13	22.98	10
22				23.23	23.26	10				20							22.98	23.12	12			
24				22.97	23.00	10				27							23.11	23.24	11	23.25	23.10	10
25				23.08	23.11	10				31										23.24	23.09	10
26				23.19	23.22	10				Nov. 1							22.96	23.11	12	23.38	23.23	10
30				23.20	23.24	9				2							22.75	22.89	7			
May 8				23.04	23.08	10	23.17	23.10	9	3										23.30	23.14	10
9				22.82	22.87	10	23.07	23.00	8	4							23.07	23.22	12			
10				23.00	23.05	9	23.27	23.22	3	6												
12				22.86	22.91	10	23.05	22.99	9	10										23.15	23.01	6
13				23.05	23.11	4				11							23.08	23.22	12	23.44	23.30	10
26				23.00	23.08	10	22.86	22.81	9	12							23.15	23.30	12			
27				22.89	22.97	8	23.08	23.03	9	15							23.00	23.14	12	23.43	23.28	8
June 3				22.75	22.83	7				16							23.10	23.24	11	23.34	23.20	9
4				22.62	22.70	6				19							22.79	22.92	12	23.37	23.22	10
8				23.09	23.17	8				20							23.17	23.31	12			
9				22.84	22.93	9				21							23.13	23.27	12			
10				23.08	23.17	10	23.04	23.01	9	22							23.01	23.15	11			
11							23.06	23.04	1	24										23.22	23.09	7
12				22.96	23.06	3				26							23.18	23.32	12			
14				22.95	23.05	9	22.86	22.84	5	27							22.78	22.91	12	23.52	23.38	3
15				23.02	23.11	10	22.95	22.93	9	28							22.93	23.07	11			
17				22.82	22.91	9	23.07	23.04	7	29							23.20	23.34	12			
18				22.87	22.98	3				Dec. 3							23.17	23.31	10	23.38	23.25	10
20				22.99	23.09	8	22.91	22.89	8	4							22.99	23.12	11	23.40	23.25	10

	IV			I			II			III				II			III			IV		
	ϕ_1	ϕ_2	No	ϕ_1	ϕ_2	No	ϕ_1	ϕ_2	No	ϕ_1	ϕ_2	No		ϕ_1	ϕ_2	No	ϕ_1	ϕ_2	No	ϕ_1	ϕ_2	No
1894	"	"		"	"		"	"		"	"		1895	"	"		"	"		"	"	
Dec. 5	23.12	23.26	11	23.21	23.08	10							May 18	23.07	23.13	10	23.19	23.14	6			
6	22.86	22.99	11	23.39	23.24	9							22	22.77	22.83	10	23.16	23.10	9			
23				23.25	23.12	10							23	22.81	22.87	10	23.18	23.13	9			
27				23.44	23.30	10							28	23.20	23.28	10	22.97	22.92	9			
28				23.45	23.33	8							29	22.90	22.98	10	23.17	23.13	9			
1895 31				23.46	23.33	10							30	23.00	23.08	10	23.18	23.14	9			
Jan 1				23.37	23.25	10							June 7	22.85	22.94	10	23.05	23.02	9			
4				23.10	22.97	10							8	22.84	22.93	10	23.12	23.09	9			
11				23.25	23.13	10							9	22.97	23.06	10	22.99	22.96	8			
14				23.22	23.10	7							11	23.01	23.10	10	23.08	23.05	9			
16				23.19	23.07	10							14	23.02	23.11	9						
19				23.26	23.14	10							16	23.16	23.27	1						
23				23.53	23.41	10							23	22.89	22.99	10						
24				23.40	23.29	10							25				23.11	23.09	9			
27				23.41	23.29	10	23.38	23.37	8				28	22.73	22.84	5						
29				23.40	23.30	2							29	22.80	22.91	3						
31				23.46	23.34	10	23.29	23.28	9				July 9				23.01	23.01	9	22.80	22.85	11
Feb. 2				23.38	23.27	10	23.15	23.14	8				10				22.93	22.94	9			
Mar. 3				23.47	23.36	10							12				23.00	23.01	9	22.94	22.98	7
5				23.58	23.48	7							16				23.08	23.10	7	22.92	22.98	12
6				23.11	23.00	3							18				22.92	22.93	9	22.84	22.88	12
9				23.46	23.36	10							19				22.79	22.80	9	22.91	22.96	12
10				23.22	23.12	5							25				22.99	23.01	9	22.76	22.81	11
14				23.04	22.95	3							26				22.86	22.89	8	22.91	22.96	10
16							23.24	23.23	10				28				22.90	22.93	9	22.92	22.97	12
17				23.23	23.13	8	23.24	23.23	10				29				22.67	22.70	7	22.86	22.92	12
18				23.47	23.37	7	23.34	23.34	9				30				22.79	22.82	9			
19				23.37	23.27	8							31				22.73	22.76	9	22.82	22.88	11
21				23.22	23.13	6	22.93	22.93	10				Aug. 3				22.90	22.94	9			
22							23.23	23.23	9				5				22.69	22.72	7			
23				23.41	23.30	5							7				22.84	22.88	9	23.03	23.11	8
25							23.15	23.15	10				8				22.91	22.95	9			
28							22.77	22.78	10				10				22.89	22.94	9	22.80	22.87	12
Apl. 10							23.18	23.19	10				12				22.92	22.96	9			
11							23.12	23.13	10				13							22.93	23.01	12
14							23.40	23.42	10				15				22.85	22.90	9	22.75	22.82	11
15							23.39	23.42	3				18				22.83	22.88	9	22.80	22.89	5
18							23.23	23.25	10				19				22.91	22.96	8	22.78	22.87	11
19							23.31	23.34	10													
20							23.09	23.12	10													
21							23.17	23.20	10													
23							23.27	23.30	10													
May 1							22.99	23.03	10													
3							23.08	23.13	9													
6							23.13	23.18	10													
9							22.97	23.02	10	22.98	22.91	9										
10										22.96	22.89	9										
12							22.82	22.89	2													
13							23.01	23.07	9													
16							22.98	23.04	10	23.03	22.97	8										

The Constant of Aberration.

In the expression for $\frac{1}{2}(\delta + \delta')$ —page 84—the terms $\frac{1}{2}(c' + c_1')C + \frac{1}{2}(d' + d_1')D$ comprise the correction for aberration. Writing for C and D their values as given in the American Ephemeris and calling the expression κ , we have

$$\kappa = 20''.4451[-\frac{1}{2}(c' + c_1') \cos \omega \cos \odot - \frac{1}{2}(d' + d_1') \sin \odot].$$

Let $20''.4451 + y$ be the true value of the constant of aberration, $\kappa + \delta\kappa$ the corresponding correction,

Then $\kappa + \Delta\kappa = (20''.4451 + y)[- \frac{1}{2}(c' + c_1') \cos \omega \cos \odot - \frac{1}{2}(d' + d_1') \sin \odot]$.

By division

$$\frac{\kappa}{\kappa + \Delta\kappa} = \frac{20''.4451}{20''.4451 + y}$$

From which $\Delta\kappa = \kappa x$ where x is written for $\frac{y}{20.4451}$

Let $\phi_1, \phi_2, \phi_3, \phi_4$ be the values of the latitude given by Groups I, II, III, IV,

$\Delta_1, \Delta_2, \Delta_3, \Delta_4$ the constant part of the correction which these values require,

The true value of the latitude will be

$$\begin{aligned}\phi &= \phi_1 + \Delta_1 + \kappa_1 x \\ &= \phi_2 + \Delta_2 + \kappa_2 x \\ &= \phi_3 + \Delta_3 + \kappa_3 x \\ &= \phi_4 + \Delta_4 + \kappa_4 x\end{aligned}$$

Employing the values of ϕ_1, ϕ_2, ϕ_3 and ϕ_4 determined on the same dates and subtracting the consecutive equations we have

$$\begin{aligned}0 &= \phi_1 - \phi_2 + (\Delta_1 - \Delta_2) + (\kappa_1 - \kappa_2)x \\ &= \phi_2 - \phi_3 + (\Delta_2 - \Delta_3) + (\kappa_2 - \kappa_3)x \\ &= \phi_3 - \phi_4 + (\Delta_3 - \Delta_4) + (\kappa_3 - \kappa_4)x \\ &= \phi_4 - \phi_1 + (\Delta_4 - \Delta_1) + (\kappa_4 - \kappa_1)x.\end{aligned}$$

Adding we find $0 = \Sigma\Delta\phi + \Sigma\Delta\kappa x$.

For deriving the value of y , those determinations of latitude were employed where both evening and morning observations were obtained on the same or consecutive dates. In three cases two days intervened between the morning and evening observations, and in one case three days.

The details are shown in the table which follows. $\Sigma\phi$ is the sum of the seconds of observed latitude for the date indicated, the foregoing corrections having been applied for reduction to mean declination of group; $\Sigma\kappa$, is the sum of corrections for aberration.

The process of assembling in groups and formation of equations seems to call for no farther explanation.

[illegible]

The two series of values for I-II, II-III, and III-IV have been combined by weights in the final expressions given below.*

		$\Delta\phi$	κ	Wt.			$\Delta\phi$	κ	Wt.
1894. Feb. 6	I-II	+.044	+19.57	1.96	1895. Jan. 30	I-II	+.142	+18.77	1.36
26		+.030	20.98	1.84	Mar. 20		+.111	19.64	1.93
Mar. 14		+.063	20.22	1.80					
Mean		+.0455	+20.24	5.60	Mean		+.1238	+19.28	3.29
May 10	II-III	-.188	+10.37	1.66	May 17	II-III	-.159	+11.17	2.55
26		-.017	11.53	0.90	29		-.073	11.43	1.42
June 16		-.018	11.17	2.47	June 9		-.147	11.57	1.87
July 2		-.050	9.82	1.07	25		-.274	10.89	0.56
Mean		-.0697	+10.77	6.10	Mean		-.1465	+11.32	6.40
July 17	III-IV	+.071	+11.69	2.86	July 15	III-IV	+.074	+11.46	2.39
Aug. 7		+.099	12.23	2.04	28		-.015	12.23	2.40
24		+.099	11.30	2.47	Aug. 13		+.030	11.52	2.79
Sep. 13		-.045	9.24	1.48					
Mean		+.0659	+11.30	8.85	Mean		+.0296	+11.73	7.58
Oct. 15	IV-I	-.224	+18.87	3.24					
Nov. 5		-.261	19.67	3.03					
20		-.387	18.56	2.42					
Dec. 4		-.312	17.03	2.05					
Mean		-.2880	+18.67	10.74					

$$\begin{aligned}
 19.88x + .0745 &= 0 \\
 11.05x - .1090 &= 0 \\
 11.50x + .0492 &= 0 \\
 18.67x - .2880 &= 0 \\
 61.10x - .2733 &= 0
 \end{aligned}$$

$$\begin{aligned}
 x &= +0.004473 \\
 y &= .0915
 \end{aligned}$$

$$\begin{aligned}
 &20.4451 \\
 \text{Aberration} &20''.5366
 \end{aligned}$$

Adopting this value of the constant of aberration as that best suited to present purposes, the necessary correction to the latitude is found by multiplying the computed reduction for aberration by the factor .004473.

After applying these corrections to the latitudes we are prepared to form the condition equations for adjusting the declination systems of the different groups in order to free the results from systematic differences.

*If we reduce these as two separate series, the term IV-I appearing in both, we find for the constant of aberration—

$$\begin{aligned}
 \text{First series, } &20''.5377 \\
 \text{Second " } &20''.5393.
 \end{aligned}$$

The Latitude.

Assembling the corrected latitudes in groups covering convenient periods, which in the present case have an average duration of about sixteen days, we have the results given below. As before $p = \frac{nn'}{10(n+n')}$.

		<i>I</i>	No.	<i>II</i>	No.	<i>III</i>	No.	<i>IV</i>	No.		$\Delta\phi$	<i>p</i>	$\frac{1}{p}$
		"		"		"		"					
1894.	Jan. 19-Feb. 16	3.201	100	3.140	31					II—I	—061	2.37	
	Feb. 19-Mar. 3	3.235	46	3.141	34					$2v_1$	—094	1.95	
	Mar. 4-Mar. 18	3.322	71	3.137	40						—185	2.56	
											—1165	6.88	.1453
	Mar. 19-Apr. 15			3.117	49								
	Apl. 16-Apr. 30			3.104	51								
	May 8-May 13			2.930	43	3.060	29			III—II	+130	1.73	
	May 26-June 15			2.961	80	2.944	42			$3v_2$	—017	2.75	
	June 17-July 5			2.908	59	2.934	43				+026	2.49	
											+0348	6.97	.1435
	July 9-July 25					3.037	59	2.939	62	IV—III	—098	3.02	
	Aug. 5-Aug. 22					2.968	61	2.803	71	$4v_3$	—165	3.28	
	Aug. 23-Sep. 15					2.991	60	2.941	70		—050	3.23	
											—1048	9.53	.1049
	Oct. 2-Oct. 20	3.218	57					3.067	110	I—IV	+151	3.75	
	Oct. 27-Nov. 12	3.269	66					3.106	66	$1v_4$	+163	3.30	
	Nov. 15-Nov. 27	3.342	37					3.082	94		+260	2.65	
	Nov. 28-Dec. 6	3.328	39					3.107	66		+221	2.45	
1894-1895.											+1921	12.15	.0823
	Dec. 23-Jan. 4	3.339	58										
	Jan. 11-Jan. 24	3.319	57										
	Jan. 27-Feb. 2	3.427	32	3.201	25					II—I	—226	1.40	
	Mar. 3-Mar. 28	3.391	72	3.063	68					$2v'_1$	—328	3.50	
											—2989	4.90	.2041
	Apl. 10-Apr. 19			3.217	53								
	Apl. 20-May 6			3.099	59					III—II	+072	4.17	
	May 9-May 30			2.970	91	3.042	77			$3v'_2$	+109	2.67	
											+0864	6.84	.1462
	June 7-June 29			2.944	68	3.053	44						
	July 9-July 31					2.919	103	2.842	110	IV—III	—077	5.08	
	Aug. 3-Aug. 19					2.917	78	2.847	59	$4v'_3$	—070	3.36	
											—0742	8.44	.1185

If we represent by $2v_1, 3v_2, \dots$ the required corrections to the observed differences (II—I), (III—II) \dots the following conditions must be satisfied:

$$\begin{aligned}
 2v_1 + 3v_2 + 4v_3 + 1v_4 &= +0056 \\
 2v_1 &= +1824 \\
 3v_2 &= -0516 \\
 4v_3 &= -0306
 \end{aligned}$$

Employing the weights given in the table preceding and solving our equations by the method of correlates, we find the following normal equations :

$$\begin{array}{rcl} .4760 k + .1453 k' + .1435 k'' + .1049 k''' & = & +.0056 \\ .1453 k + .3494 k' & & = +.1824 \\ .1435 k & + & .2897 k'' = -.0516 \\ .1049 k & & + .2234 k''' = -.0306 \end{array}$$

From which

Also

$$\begin{array}{rcl} k & = & -.1026 \\ k' & = & +.5647 \\ k'' & = & -.1272 \\ k''' & = & -.0888 \end{array} \qquad \begin{array}{rcl} {}_2v_1 & = & .1453(k + k') = +.0671 \\ {}_3v_2 & = & .1435(k + k'') = -.0330 \\ {}_4v_3 & = & .1049(k + k''') = -.0201 \\ {}_1v_4 & = & .0823 k = -.0084 \\ {}_2v'_1 & = & -.2041 k' = -.1153 \\ {}_3v'_2 & = & -.1462 k'' = +.0186 \\ {}_4v'_3 & = & -.1185 k''' = +.0105 \end{array}$$

Therefore for the corrected differences

$$\begin{array}{rcl} \text{II} - \text{I} & = & -.1836 \\ \text{III} - \text{II} & = & +.0678 \\ \text{IV} - \text{III} & = & -.0847 \\ \text{I} - \text{IV} & = & +.2005 \end{array}$$

The algebraic sum should, of course, be zero.

From these relations

$$\begin{array}{rcl} \text{I} & = & \text{II} + .1836 \\ & = & \text{III} + .1158 \\ & = & \text{IV} + .2005 \end{array}$$

Subtracting 0.1250 from each side of our equations in order to make the sum of the corrections zero, we obtain the following values, which must be applied to the latitudes derived from the respective groups in order to reduce all to a homogeneous system :

$$\begin{array}{rcl} \text{I} & - & 0.125 \\ \text{II} & + & 0.059 \\ \text{III} & - & 0.009 \\ \text{IV} & + & 0.075 \end{array}$$

Applying these corrections to the values of the latitudes given on page 150, we obtain the final results, as follows:

Final Values of Latitude—All Corrections Applied.

Weighted Mean Date.			I	No.	II	No.	III	No.	IV	No.	Mean ϕ
1	1894	Feb. 4	3.076	100	3.199	31					3.137
2		Feb. 25	3.110	46	3.200	34					3.155
3		Mar. 13	3.197	71	3.196	40					3.196
4		Apl. 9			3.176	49					3.176
5		Apl. 25			3.163	51					3.163
6		May 10			2.989	43	3.051	29			3.020
7		June 6			3.020	60	2.935	42			2.977
8		June 25			2.967	59	2.925	43			2.946
9		July 16					3.028	59	3.014	62	3.021
10		Aug. 13					2.959	61	2.878	71	2.918
11		Sep. 5					2.982	60	3.016	70	2.999
12		Oct. 14	3.093	57					3.142	110	3.117
13		Nov. 4	3.144	66					3.181	66	3.162
14		Nov. 21	3.217	37					3.157	94	3.187
15		Dec. 4	3.203	39					3.182	66	3.192
16		Dec. 29	3.214	58							3.214
17	1895	Jan. 18	3.194	57							3.194
18		Jan. 31	3.302	32	3.260	25					3.281
19		Mar. 17	3.266	72	3.122	68					3.194
20		Apl. 15			3.276	53					3.276
21		Apl. 27			3.158	59					3.159
22		May 20			3.029	91	3.033	77			3.031
23		June 13			3.003	68	3.044	44			3.024
24		July 21					2.910	103	2.917	110	2.914
25		Aug. 12					2.908	78	2.922	59	2.915
				635		751		596		708	

The folded sheet which follows gives the individual values of the seconds of latitude, all corrections and reductions having been applied.

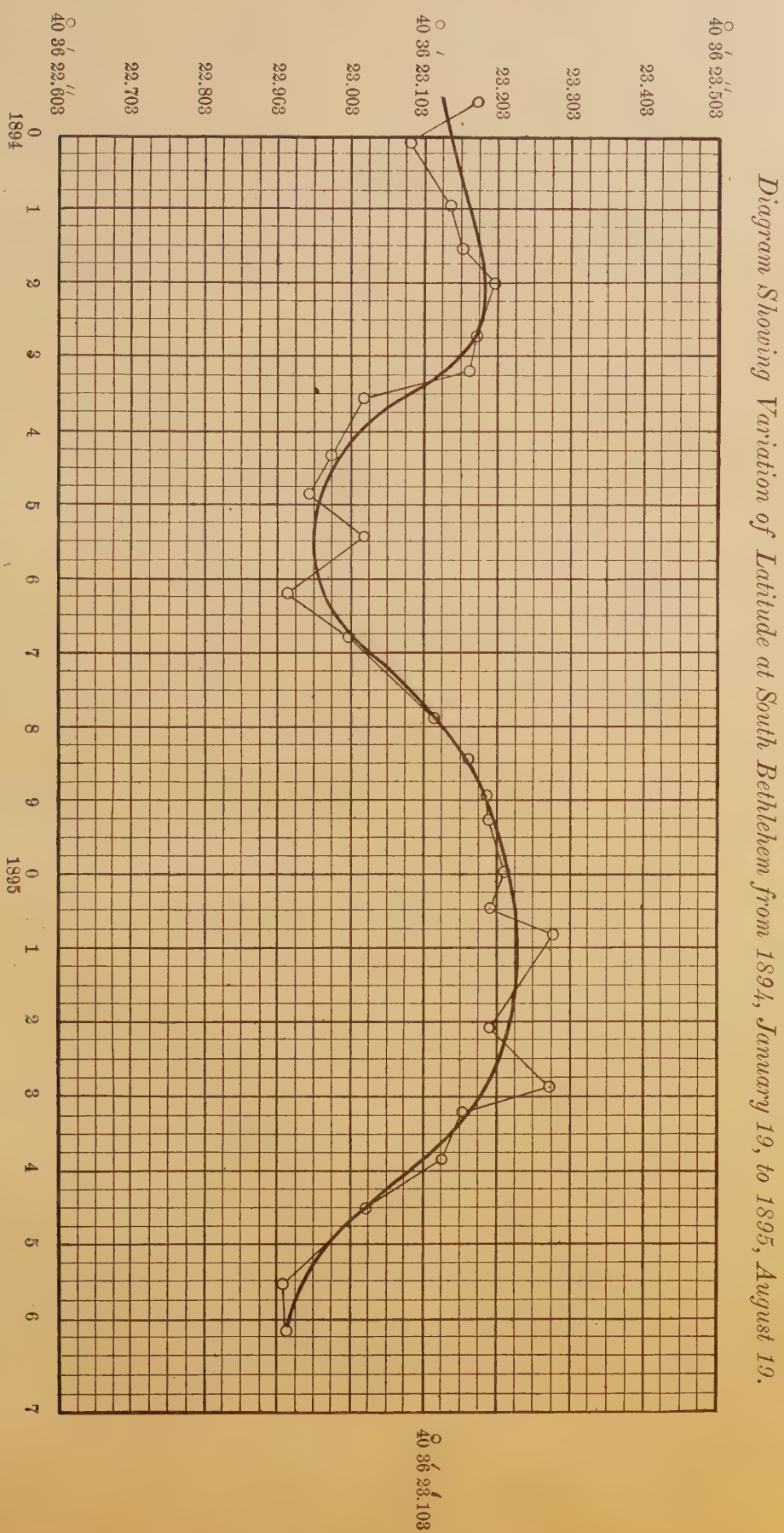
The probable error of a single determination has been derived from these final values, and therefore includes that part due to the adjusted declinations as well as that of observation.

The results are as follows:

For Group	I	$r=0''.218$	from 635 residuals
	II	.212	751
	III	.189	596
	IV	.193	708
Mean		$r=0''.203$	2690 = whole number of latitude determinations.

[illegible]

OBSERVATIONS WITH THE ZENITH TELESCOPE.



ARTICLE IV.

A STUDY OF THE CHROMOSOMES OF THE GERM CELLS OF METAZOA.

Plates IV—VIII.

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I. INTRODUCTION.

The present study is practically a continuation of previous work of mine upon spermatogenesis in the Arthropods. It was undertaken primarily to correct certain errors of interpretation and observation in my work on *Pentatoma* (*Euchistus*). But many morphological problems arose in connection with this reëxamination, such as the significance of the changes in the synapsis stage, the significance of the chromatin nucleoli, the reasons for a reduction division, the significance of the sequence of the stages of the germinal cycle, and the question as to why different species have different numbers of chromosomes. Thus my investigations given here are essentially on the history of the chromosomes during the germinal cycle.

It is impossible to answer these problems by an examination of a single species, and accordingly there are presented here the results of a comparative study of the spermatogenesis of some forty-two species of *Hemiptera heteroptera*, belonging to twelve different families. This comparative study has brought to light certain wholly unexpected phenomena, and none less anticipated than the discovery of four species with an uneven normal number of chromosomes; this discovery has furnished facts for explaining how the chromosomal numbers may change with the evolution of the species, and how the chromatin nucleoli may have originated. And only such a comparative study could furnish facts to show that in the synapsis stage bivalent chromosomes are formed by the union of paternal with maternal chromosomes—*i. e.*, that this is the stage of conjugation of the chromosomes. The comparative method in Cytology cannot be overestimated, though of course careful detailed examinations of single objects should be carried on at the same time. For a single object is rarely capable of serving as the basis of explana-

tion of all the problems; an investigation of a number of forms always shows that some are more favorable than others for answering certain questions, and then there is the chance that a wholly unexpected discovery may be made that may have great significance. So the plea is made here for the comparative method in Cytology, and Cytology should not be ranked as a line of work separate from others—it is all Morphology in the broad sense of the term, and it only happens that in Cytology we use higher magnification powers of the microscope than in other lines. If one form shows phenomena that seem inexplicable after careful work, then the proper method, the one that would promise a surer reaching of results, is not to reëxamine this form again and again, but to compare other forms in the search for the explanation.

In the present paper the part containing the general conclusions may appear proportionally great to the record of the observations. These observations are to great extent on the number and valence of the chromosomes and chromatin nucleoli from the time of the last generation of the spermatogonia up to the formation of the spermatids. But the determination of these numbers is very difficult; large numbers of sections have to be examined in order to find the necessary stages, and the number of the chromosomes of each stage have to be counted in a considerable number of cells of each species in order to insure accuracy. The counting has been done in all cases by selecting those cells in which the chromosomes are most loosely grouped, being sure at the same time that all the chromosomes are in the plane of the section, drawing the chromosomes carefully with the camera lucida, then counting their number on the drawings. This demands much patience and time, necessitating also constant reëxaminations and study of new material, though the results may be tabulated in a very small space. Of course the difficulties are most pronounced where the chromosomes are numerous and small.

The material was collected by me at two localities—in the vicinity of Philadelphia, Pennsylvania, and in the neighborhood of Wood's Holl, Massachusetts. Great care was taken to insure accurate identification of the species, and my specimens were directly compared by me with the collections in the museums of the Wagner Institute of Science and of the Academy of Natural Sciences of this city; these collections had been labeled by Dr. P. R. Uhler, of Baltimore, our foremost American authority on this group of Insects; and I must also acknowledge my indebtedness to Dr. Uhler for kindly identifying a number of species which were not represented in the collections just mentioned. To my friend, Mr. C. W. Johnson, curator of the Wagner Institute, my thanks are also due for aid in identification. The differences of the spermatogenetic phenomena of different species shows how important it is to secure accurate identification.

The testes were removed as rapidly as possible from the living animals and immediately placed in the fixing fluids, Flemming's chemo-aceto-osmic acid mixture (the

stronger solution), Hermann's chromo-aceto-platinic chloride mixture, and a picro-acetic mixture recommended by Prof. Conklin (100 parts saturated aqueous solution of picric acid, 100 parts distilled water, 6 parts glacial acetic acid) being used. Of these the mixtures of Flemming and Hermann proved the best for the chromosomal structures, for the picro-acetic mixture, while giving an excellent preservation of the actromatic spindle structures, swells the chromosomes very considerably so that on pole views of monaster stages they generally appear closely apposed to one another, which makes it difficult to count them. Where the species is small it is necessary to remove the testes in the fixative under a dissecting microscope. The sections were stained either by the iron-hæmatoxylin method of Heidenhain or by the saffranine-gentian violet method of Hermann.

II. OBSERVATIONS.

PENTATOMIDÆ.

1. *Euchistus variolarius* Pal. Beauv.

This is the species the spermatogenesis of which I described under the name of "*Pentatoma*" in a former paper (1898); twenty-eight testes were studied from adult individuals of all seasons except the winter months.

In my former paper (*l. c.*) I did not find chromatin nucleoli in the spermatogonia; I concluded that there was no stage of longitudinal splitting of the chromosomes during the growth period, and I concluded that the second maturation division was a reduction mitosis like the first. Shortly afterward appeared the papers by Paulmier (1898, 1899) on the spermatogenesis of *Anasa tristis*, wherein he showed that there are two chromatin nucleoli (his "small chromosomes") in the spermatogonia, and that these unite in the spermatocytes to form one bivalent one; that the chromosomes undergo a longitudinal splitting in the growth period, and that the second maturation division is equational. In those points wherein I differed from Paulmier, I find that Paulmier is correct, and that I gave a wrong interpretation to the phenomena in *Euchistus*. I find nothing to correct in the matter of the other points described in my earlier account, and here give briefly merely the necessary emendations to my former paper.

Spermatogonia.—In the resting spermatogonium there are in the nucleus beside the true nucleolus (of which there may be more than one) two small chromatin nucleoli of rounded form (Plate I, Fig. 1, *N. 2*). With the saffranine-gentian violet stain of Hermann, when properly used, these stain bright red, the true nucleolus a faint bluish, the chromatin proper a deep violet; careful staining and thin sections are necessary to show them plainly. Sometimes one or both of them are attached to a true nucleolus. In the prophases of mitosis the chromatin nucleoli are easily recognizable by being much smaller

and more spherical than the chromosomes. In the monaster stage, in favorable cases where the chromatic elements are not too densely arranged, are seen fourteen larger elements, the chromosomes proper, and two smaller ones regularly rounded in form, which are the chromatin nucleoli (Figs. 2, 3, *N. 2*). Sometimes the chromosomes are rounded, but since they frequently appear slightly elongate on pole view of the spindle, their division in metakinesis must be an equational one. In the metakinesis all sixteen elements, the fourteen chromosomes and the two chromatin nucleoli, are divided, so that each daughter cell (first spermatocyte) receives sixteen elements.

Thus there are two chromatin nucleoli in the spermatogonia, and the chromatin nucleolus of the spermatocytes is not, as I had previously described, formed by a modification of one of the fourteen chromosomes of the spermatocytes, but is derived from the two of the spermatogonia. My error was perhaps excusable, since in restudying the preparations which were used for my former paper I find that they are not suitably stained to show the chromatin nucleoli in the spermatogonia.

Growth period of the spermatocytes (anaphases of the last spermatogonic division, synapsis, postsynapsis, telophase and rest).—The fourteen chromosomes in each daughter cell (first spermatocyte) pass toward the pole of the spindle and become irregular in contour and form. Then each becomes longitudinally split (Figs. 4–11). This splitting cannot be clearly seen in all preparations, and is by no means as clear as in *Anasa* and certain other *Hemiptera*; the preparations of my former paper were too deeply stained to show it. The split commences in the early synapsis stage (Fig. 4) and is most marked in the postsynapsis (Fig. 9), and is clearly a single longitudinal split. Never do the split halves separate widely from one another, as Paulmier found for *Anasa*, but always appear to remain close together and approximately parallel; at the most there is a divergence only at the ends of the chromosomes. On deep staining the split may be easily overlooked. The two chromatin nucleoli do not become loose in texture, retain their characteristic red stain with saffranine, and join together in the early synapsis to form one dumbbell-shaped (bivalent) one (*N. 2*, Figs. 4, 5, 8, 10); they do not become longitudinally split like the chromosomes proper. In the early synapsis they are frequently very irregular in form, as I showed in my previous paper, but the apparent fragmentation of them which I then described—a fragmentation of a single long one into two—is not a fragmentation at all, but a stage before the two have joined to form one bivalent one.

Reduction in number of the chromosomes.—In my earlier paper I showed that the number of chromosomes is reduced one-half during the synapsis period—*i. e.*, long before the maturation divisions. I then considered it probable that the reduction in number was effected by a union of chromosomes end to end, but was unable to prove this point. Since then I have been able to demonstrate that this numerical reduction is effected in

the synapsis by the union into seven pairs of the fourteen chromosomes, each of the seven bivalent chromosomes (pairs) being composed of two univalent chromosomes joined end to end (Figs. 5-11). Where the ends of two univalent chromosomes come together is seen a connecting band of linin; each bivalent chromosome during the synapsis and postsynapsis is U- or V-shaped, and the bend or angle of the U or V marks the point of union of two univalent chromosomes; the arms of the U or V are longitudinally split. In each bivalent chromosome only one end of each univalent chromosome is thus closely connected with one end of the other, the opposite ends of the univalent chromosomes having no such linin connections. It has been already mentioned that the two chromatin nucleoli come together likewise to form one bivalent one, and it can be seen that they are connected by a band of linin.

In a paper on the spermatogenesis of *Peripatus* (1901) I showed that it is a particular end of one univalent chromosome which unites with a particular end of another; these ends are the ones which point nearest to the pole of the spindle in the anaphase of the last spermatogonic mitosis, the "central ends," as I have called them, in distinction to the opposite or "distal ends." In *Euchistus*, on the contrary, I am unable to determine positively whether it is similar ends of chromosomes which unite, because in this form the chromosomes have a much more irregular position within the nucleus; the polarity of the nucleus is not so well marked as in *Peripatus*. In the cell body the polarity is as in *Peripatus*: that pole with the greatest amount of cytoplasm and containing the idiozome mass is the distal pole (the one which in the dyaster stage of the last spermatogonic division was in the equator of the cell). This polarity of the cell body is shown in Figs. 4, 5 and 8; I figured it also in a number of cases in my previous paper, but then erroneously supposed the idiozome mass to occupy that point where the spindle pole had previously been, whereas I am now able to determine positively that this pole is situated directly opposite, namely, where the least amount of cytoplasm is situated. Now it would appear in *Euchistus*, though not nearly so regularly as in *Peripatus*, that it is the openings of the U- or V-shaped bivalent chromosomes that are directed toward the distal pole of the cell body (toward the pole where the idiozome mass is placed). Figs. 4, 5 and 8 show this for certain of the chromosomes, while other ones (as two in Fig. 5) may have their openings in opposite directions. Thus in *Euchistus* there is more irregularity in the positions of the axes of the chromosomes, so that I have been unable to determine whether it is, as in *Peripatus*, only particular ends of the univalent chromosomes which unite with particular ends of others.

Throughout the growth period can be seen two kinds of linin threads: (1) thicker threads which connect the ends of the chromosomes, and (2) more delicate ones which join chromatin granules with the nuclear membrane. Apparently, as I have shown for

Peripatus, the former, together with the linin contained in the chromosomes (axial threads), together constitute a single continuous linin spirem in the nucleus.

Rest stage of the spermatocytes.—A rest stage in the growth period preceding the prophases of the maturation mitoses is well marked in *Euchistus* (Fig. 12 and Figs. 95–100 of my preceding paper); though I can confirm Paulmier's observation that such a stage does not occur in *Anasa*. It is characterized by a huge true nucleolus, by a rather diffuse and scattered distribution of the chromatin so that chromosomal boundaries are practically indistinguishable, and by the diffuse arrangement of a great amount of idiozome substance all around the nucleus, so that an idiozome mass with sharp outlines is not present; the idiozome mass in the synapsis stage (Figs. 4, 5, 8), on the contrary, had a sharp and distinct outline. The bivalent chromatin nucleolus has now become nearly rounded in form, rarely showed a dumbbell shape, so that its component parts are very closely apposed. It lies peripheral, in contact with the nuclear membrane, while the true nucleolus lies nearer the centre of the nucleus. Sometimes a much smaller rounded body, staining like the chromatin nucleolus, is also found in the nucleus, but what its origin is I have not been able to determine, for I have not found it in the spermatogonia, though it might well escape detection there on account of its small size.

As to the terminology adopted by me in my former paper (1898) for the series of stages of the growth period, which has been criticised by McClung (1900), the term "metaphase" was, I grant, used by me incorrectly, for I used it for the commencement of the anaphase, whereas it is really Strasburger's stage comparable to Flemming's "metakinesis." However, the exact use of these terms was explained by me (1898, p. 20). In the stages leading up to the resting spermatocyte I distinguished "early anaphase," "synapsis," "postsynapsis," and "telophase" as easily recognizable stages in the growth period of *Euchistus* which need to be characterized by terms for purposes of description. McClung (*l. c.*) considers the appearances of the synapsis stage as artefacts; it is hardly necessary to reply to this criticism, since in all *Metozoa* where the spermatogenesis has been carefully examined, with the exception of certain *Amphibia*, the dense massing of the chromosomes in the synapsis stage has been shown to be a perfectly normal phenomenon. As to my use of "telophase," Heidenhain's (1894, p. 524) definition is: "Unter dem Namen Telokinesis beschreibe ich gewisse Bewegungen des Kerns und des Mikrocentrums, welche gegen das Ende der Mitose hin stattfinden. . . . Die zugehörigen Stadien der Mitose bezeichne ich als Telophasen." Since Heidenhain employed it for the stage just preceding rest in leucocytes, I was warranted in using it for the stage just before the rest stage in the spermatocytes of *Euchistus*. It must be borne in mind, in the description of the changes of the growth period of the germ cells, that a peculiar stage, the synapsis, occurs, not found elsewhere in mitosis, and that this stage modifies to greater or

less extent, according to the object, the stages which precede and those which succeed. It results from this that the stages of mitosis of the growth period cannot be exactly compared with those of other cells, and hence the terms "anaphase" and "telophase" can here have a significance only approximately similar to that of other mitoses.

The maturation divisions.—In the early prophases the longitudinal splitting of the chromosomes is well marked, clearer than in preceding stages (Figs. 13, 14). Each chromosome is, as before the rest stage, clearly bivalent, formed of two longitudinally split univalent chromosomes joined so as to make an angle together (Figs. 13–15), and at the bend of the angle is a connecting linin thread. These forms of the bivalent chromosomes were clearly figured in my earlier paper, except that then I had overlooked the longitudinal split. The chromosomes gradually become closer, shorter, with smoother outlines, the longitudinal split gradually becomes hidden, and the definitive chromosome with the form of a dumbbell results (Figs. 16–18). In the definitive chromosome there is usually no trace of the longitudinal split, except occasionally as a slight indentation at the free end of a univalent component. The constriction of the dumbbell marks the point of union of two univalent chromosomes, which is effected by a linin band which generally never becomes quite hidden.

In the late prophases, just before the disappearance of the nuclear membrane, and when the centrosome pairs have reached opposite poles of the nuclear surface, a remarkable condition of the linin threads is found (Fig. 17); it was also shown in Figs. 152 and 153 of my earlier paper. The linin, previously in the form of fibres or strands, now takes the form of chains of small globules—quite as Van Beneden (1883) had figured for *Ascaris*. I cannot explain this condition, but I have found it always at this stage, and at this stage only.

In the first maturation division there are seven bivalent chromosomes and one bivalent chromatin nucleolus, and all these elements are divided transversely in metakinesis, being placed in the monaster stage so that their constrictions lie in the plane of the equator. Fig. 18 shows a monaster stage with all these elements on lateral view, Fig. 19 on pole view; this stage was accurately described by me in my former paper, so that I have no additions to make to that description. Whole univalent chromosomes are separated in the ensuing metakinesis, and the univalent components of the chromatin nucleolus are also separated.

When the daughter chromosomes separate in the anaphase a constriction or indentation appears on them (Figs. 193–201 of my preceding paper). This I am now able to prove, in agreement with Paulmier's observations on *Anasa*, is the reappearance of the longitudinal split; this indentation or constriction becomes placed in the equatorial plane of the monaster stage of the second maturation division, so that the latter division divides

the chromosomes equatorially. In the anaphase of the first maturation division the constriction of the chromosomes generally has the appearance shown in Fig. 195 of my former paper; while Fig. 196, which I then considered to represent the typical condition, I now, from the study of more abundant material, find to be an unusual condition. That is to say, the appearance of the chromosomes shown in Fig. 196 of my preceding paper is really atypical, since in this case their constrictions appear at right angles to the long axis of the spindle, whereas in most other cases the planes of these constrictions coincide with planes passing through the long axis of the spindle. In this second maturation division the chromatin nucleolus is not always divided.

2. *Euchistus tristigmus* Say

Four testes of this species were studied.

In the rest stage of the spermatogonium there are two small chromatin nucleoli, generally attached to the surface of the true nucleolus.

In the spermatogonic mitosis there are fourteen chromatin segments in the equatorial plate (Pl. I, Fig. 20); the twelve larger, usually somewhat elongate ones are chromosomes, and the two smallest, rounded ones are chromatin nucleoli. All these elements are halved in metakinesis.

In the synapsis stage the twelve chromosomes unite to form six bivalent chromosomes. The two chromatin nucleoli sometimes unite to form a bivalent one, which is clearly dumbbell-shaped in earlier stages, but in the resting spermatocyte becomes rounded and has a peripheral position (Fig. 22); or quite as frequently they remain separate from one another during the growth period, and are seen to be of unequal volumes (Fig. 21). The chromatin nucleoli in the growth period are rarely attached to the true nucleolus.

In the first maturation division there are always six clearly bivalent, dumbbell-shaped chromosomes and either one dumbbell-shaped bivalent chromatin nucleolus or, apparently more frequently, two univalent chromatin nucleoli of more or less rounded form and different volume (lateral view shown in Fig. 25, N. 2). Accordingly, on pole views of the monaster stage there are seen either seven chromatin elements (Fig. 24), which are six bivalent chromosomes and one bivalent chromatin nucleolus, or there are eight, namely, six bivalent chromosomes and two univalent chromatin nucleoli (Fig. 23: in this figure one of the chromatin nucleoli can be distinguished by its smaller size, but which of the remaining seven elements is the other chromatin nucleolus is not easily discernible on pole views, since the larger of the two chromatin nucleoli has a diameter equal to that of one of the smaller chromosomes).

All the six chromosomes are halved (by a reduction division) in metakinesis, so that

in the monaster stage of the second division there are six univalent chromosomes, the constrictions of which represent the reappearance of the longitudinal split (Fig. 26); there are also in the same equatorial plate two non-constricted bodies of different volumes which are not joined together. These are the chromatin nucleoli, which are regularly halved in the first maturation metakinesis—that is, they are the halves of univalent ones. Thus the bodies marked *N. 2* in Fig. 26 are the halves of those similarly marked in Fig. 25.

The second maturation division is equatorial, and the spermatid receives six chromosomes, arranged in an outer circle around a single central chromatin nucleolus. Accordingly in this second division one chromatin nucleolus passes undivided into one daughter cell (spermatid), the other undivided into the other daughter cell.

As in *Euchistus variolarius*, two follicles of the testis contain spermatocytes of a much larger size than those in the four other follicles.

3. *Podisus spinosus* Dall.

Five testes of this species were studied.

In the spermatogenic rest stage there are two small chromatin nucleoli, of more or less rounded form, attached to the surface of a true nucleolus.

In the spermatogenic monaster there are sixteen chromatin segments (Pl. I, Fig. 27), two of which probably correspond to the chromatin nucleoli of the previous rest stage.

In the synapsis the fourteen chromosomes unite to form seven bivalent chromosomes. The two chromatin nucleoli also come together to make one bivalent one; in the growth period of the spermatocytes (Fig. 28) the chromatin nucleolus lies close to the nuclear membrane, and to its inner surface the true nucleolus is regularly attached.

In the first maturation monaster there are eight chromatin elements, namely, seven chromosomes and one chromatin nucleolus, all bivalent and dumbbell-shaped on lateral view; the chromatin nucleolus has about the same volume as the smaller ones of the chromosomes, and so cannot be distinguished from them with certainty.

4. *Mormidea lugens* Fabr.

Five testes were studied.

In the rest stage of the spermatogonia there are two chromatin nucleoli (Pl. I, Fig. 30, *N. 2*), which may be equal or unequal in size; they may be attached together, which is apparently the general rule, or may be separated, and one or both of them may be apposed to the true nucleolus.

In the spermatogenic monaster there are sixteen chromatin segments; two of these

which are smaller than the others and more rounded are the chromatin nucleoli (Fig. 31, *N. 2*).

In the synapsis the fourteen chromosomes unite to form seven bivalent ones, and the two chromatin nucleoli to form one bivalent chromatin nucleolus. The latter is peripherally placed in the nucleus, and not attached to the true nucleolus (Fig. 32).

In a pole view of the monaster stage of the first maturation division are found eight chromatin elements (Fig. 33); lateral view shows all are bivalent and dumbbell-shaped, seven are chromosomes, and one easily recognizable by its much smaller size in the chromatin nucleolus (Fig. 33, *N. 2*).

5. *Peribalus limbolaris* Stal.

Two testes of this species were studied.

In the rest stage (Pl. I, Fig. 34) and prophases of the spermatogonia are found two chromatin nucleoli of unequal size (*N. 2*), and sometimes apparently three; they are generally not in mutual contact, though they are often apposed to the true nucleoli, of which there are frequently two or three.

In the spermatogonic monaster (Fig. 35) are sixteen chromatin segments, of which the two smallest, rounded ones are the chromatin nucleoli; the fourteen chromosomes are notably elongated.

In the synapsis the fourteen chromosomes unite to form seven bivalent ones, and the two chromatin nucleoli to form one bivalent chromatin nucleolus; in the rest stage of the spermatocytes (Fig. 36) the chromatin nucleolus (*N. 2*) is usually rounded and peripherally placed, and generally unattached to the relatively very large true nucleolus (sometimes there are two true nucleoli, as in Fig. 36, rarely three). In the rest stage of the spermatocytes there is a smaller chromatin nucleolus in addition to the larger one already described, and this smaller may correspond to the third of the chromatin nucleoli found sometimes in the rest stage of the spermatogonia.

In the monaster stage of the first maturation division there are eight chromatin segments (Fig. 37), namely, seven bivalent, dumbbell-shaped chromosomes and one much smaller bivalent, dumbbell-shaped chromatin nucleolus.

6. *Cosmopepla carnifex* Fabr.

Five testes of this species were studied.

In the monaster stage of the spermatogonia (Pl. I, Fig. 38) are found eighteen chromatin segments; two of these are smaller than the others, and so by analogy with other species of this family probably represent chromatin nucleoli (*N. 2*, Fig. 38); the sixteen other segments are then true chromosomes.

In the synapsis stage of the growth period the sixteen chromosomes unite to form eight bivalent chromosomes, and the two chromatin nucleoli to form one bivalent chromatin nucleolus. The latter is, in the rest stage of the spermatocytes, rounded and peripheral in position, and is not attached to the larger true nucleolus (Fig. 39); both the nucleolus and the chromatin nucleolus may contain a large, clear vacuole, which in the former is excentric.

Pole views of the monaster stage of the first maturation division show nine chromatin elements (Fig. 41), and lateral views (Fig. 40) of the same stage show that all are bivalent and dumbbell-shaped. The smallest of these elements is the chromatin nucleolus (*N. 2*).

7. *Nezara hiliaris* Say

Five testes of this form were studied.

There are in the rest stage and early prophases of the spermatogonia two chromatin nucleoli, which are comparatively large and usually more or less unequal in size (Pl. I, Figs. 42, 43, *N. 2*). They are generally peripheral in position and in mutual contact, but usually are not apposed to the true nucleolus (*N*).

In the spermatogonic monaster there are sixteen chromatin segments (Fig. 44), of which two can be always recognized by their small size and rounded form as the chromatin nucleoli; the fourteen chromosomes are generally elongated.

In the synapsis the two chromatin nucleoli unite to form one bivalent one, and apparently also the fourteen chromosomes join to make seven bivalent chromosomes, but I cannot state this with certainty. In the telophase of the spermatocytes (Fig. 45), the chromatin nucleolus (*N. 2*) is peripherally placed and clearly bivalent, and usually not in connection with the very large true nucleolus (*N*), which is also peripheral.

In the testes examined (all from individuals secured in the month of September) were stages only from the resting spermatogonia to the telophase of the spermatocytes; all later stages in the spermatogenesis were absent, so that the number of the chromosomes in the maturation divisions could not be determined.

The longitudinal split in the chromosomes during the growth period is unusually distinct in this species.

8. *Brochymena* sp.

Three testes of this species were studied.

In the rest stage of the spermatogonia (Pl. I, Fig. 46) are two small chromatin nucleoli (*N. 2*), which are peripheral in position, of nearly equal size, generally mutually apposed, and seldom attached to the true nucleolus.

In the spermatogonic monaster stage (Pl. I, Fig. 47) are sixteen chromatin segments, of which two are smaller and rounded and are the chromatin nucleoli.

In the synapsis stage the fourteen chromosomes unite to form seven bivalent ones, and the two chromatin nucleoli to form one bivalent chromatin nucleolus. The latter in the stages following the synapsis is rounded and peripheral in position (*N. 2*, Fig. 48, Pl. II), and only occasionally attached to the true nucleolus (*N*).

Pole views of the first maturation monaster (Pl. II, Fig. 49) show eight chromatin segments, of which one easily distinguishable from the others by its smaller size is the chromatin nucleolus (*N. 2*). Lateral views of this stage show that all eight of these elements are bivalent and dumbbell-shaped.

9. *Perillus confluens* H.-S.

Two testes of this species were examined.

The rest stage of the spermatogonia (Pl. II, Fig. 50) shows two small, rounded chromatin nucleoli of unequal size, which are always attached together, and may be either close to the nuclear membrane or apposed to the surface of a true nucleolus (*N*).

In the monaster stage of the spermatogonic divisions are sixteen chromatin segments (Fig. 51). The fourteen largest are chromosomes, the two smallest are chromatin nucleoli (*N. 2*); the latter are more minute than in the corresponding stage of any other Pentatomid examined by me, and on account of their small size cannot always be seen (*i. e.*, in cases where they are closely apposed to the chromosomes).

In the synapsis stage the fourteen chromosomes unite to form seven bivalent ones and the two chromatin nucleoli to make one bivalent chromatin nucleolus. The latter is dumbbell-shaped in the earlier stages of the growth period, but in the rest stage (*N. 2*, Fig. 52) becomes oval in outline, and it is then attached to the surface of the larger true nucleolus (*N. 2*), the two occupying a more or less central position within the nucleus.

Pole views of the monaster stage of the first maturation division show eight chromatin segments of varying diameter (Fig. 53); one of these, probably the smallest, is the chromatin nucleolus; lateral views show that all these elements are bivalent and dumbbell-shaped.

10. *Cœnus delius* Say

Three testes of this species were studied.

In the rest stage of the spermatogonia there are two chromatin nucleoli with irregular outlines (Pl. II, Fig. 54, *N. 2*), and they are situated usually close together.

In the spermatogonic monaster stage (Fig. 55) there are fourteen chromatin segments, the two smallest of which are probably the chromatin nucleoli (*N. 2*), leaving twelve chromosomes.

In the synapsis stage the twelve chromosomes unite to form six bivalent ones. The

two chromatin nucleoli found in the spermatogonia also unite to form one bivalent chromatin nucleolus; this is clearly bilobed in the earlier stages, but more rounded in the later stages of the growth period of the spermatocytes (the larger of the bodies designated *N. 2* in Figs. 57, 58, 63); there is attached to it usually a small true nucleolus (Fig. 58). Besides this large bivalent chromatin nucleolus there is also found in the spermatocytes, most clearly seen in the rest stage, another much smaller one, of rounded form (the smaller of the bodies marked *N. 2* in Figs. 57, 58, 63); this is almost always apposed to one of the true nucleoli (*N*), of which there are generally two large ones besides the small one attached to the large chromatin nucleolus; quite frequently the small chromatin nucleolus lies between the large one and a large true nucleolus (Fig. 63). This small chromatin nucleolus is difficult to see in the synapsis stage, when the chromosomes stain deeply, and since I was also unable to find it in the monaster stage of the spermatogonia, I could not determine whether it is bivalent or univalent or what its earlier history is. It might well be present, however, in the spermatogonia, but be there so minute as to escape detection.

Pole views of the monaster stage of the first maturation division show sometimes only seven chromatin segments (Fig. 62), and then these are six bivalent chromosomes and the large bivalent chromatin nucleolus; or they show eight segments (Figs. 59, 60), of which the smallest is the small chromatin nucleolus of the growth period. That is to say, in the equatorial plate there are always six bivalent chromosomes and the large bivalent chromatin nucleolus, while the small chromatin nucleolus may be present or may be absent. The lateral view of this stage given here (Fig. 61) shows seven large dumb-bell-shaped elements, of which six are chromosomes and one the bivalent chromatin nucleolus—though which one it would be hard to say, for all of these elements are of approximately equal size and similar form; while the smallest, eighth, element marked *N. 2* in this figure is the small chromatin nucleolus. When the latter persists into this stage it appears to be halved in the following metakinesis.

II. *Trichopepla semivittata* Say

Four testes of this species were studied.

In the nucleus of the resting spermatogonium are seen clearly two rounded chromatin nucleoli (*N. 2*, Fig. 64, Pl. II), of different volumes, one or both frequently apposed to a larger true nucleolus (*N*).

In the monaster stage of the spermatogonia are found sixteen chromatin segments, of which fourteen are elongate chromosomes, and two which are smaller and rounded are the chromatin nucleoli (*N. 2*, Fig. 65), which here, as in the preceding rest stage, are unequal in size.

In the following synapsis stage the fourteen chromosomes join to form seven bivalent ones. The two chromatin nucleoli likewise unite to form one bivalent one, of which the two components are unequal in size (Fig. 66, *N. 2*). In the telophase and rest stage of the spermatocytes the chromatin nucleolus loses its earlier bipartite form and becomes rounded (the larger of the bodies marked *N. 2* in Fig. 67), and only occasionally is it apposed to the larger true nucleolus (*N*). Sometimes the two chromatin nucleoli derived from the spermatogonia do not unite together, but remain separated. During the growth period, its later stages at least, can be seen in each nucleus three or four much smaller, rounded bodies, which stain like the chromatin nucleoli; some of them are often attached to the surface of the true nucleolus (Fig. 67, the three smaller bodies designated *N. 2*). There are certainly three of them and in some nuclei apparently four. I was unable to determine with certainty these small chromatin nucleoli in the rest and division stages of the spermatogonia, though they might well be present there, but escape observation on account of their minuteness.

The monaster stage of the first maturation division (Figs. 68, 69) shows eight larger, bivalent, dumbbell-shaped chromatin segments, of which seven are chromosomes and one the large chromatin nucleolus (*N. 2* of the figures). Of the seven chromosomes one is always longer and more voluminous than the others (Figs. 68, 69), and is probably the derivative of the two largest chromosomes found in the spermatogonic divisions (Fig. 65). Besides these eight large elements of the monaster stage of the reduction division there may be seen on pole view usually one (Fig. 68), sometimes two much smaller granules, which evidently represent the small chromatin nucleoli found in the growth period.

SCUTELLARIIDÆ.

12. *Eurygaster alternatus* Say

Three testes of this form were studied from individuals taken in July and August. Each testis was filled with spermatocytes and spermatids, but contained no spermatogonia.

In the spermatocyte in the rest stage one bilobed and hence probably bivalent chromatin nucleolus (*N. 2*, Fig. 70, Pl. II), which is peripheral in position and separated from the usually smaller true nucleolus (*N*). Sometimes the two components of this chromatin nucleolus do not join together in the synapsis but remain separated through the growth period.

In the monaster stage of the first maturation division (Fig. 71, pole view) are found seven dumbbell-shaped (and hence probably bivalent) chromatin segments, of which the smallest is undoubtedly the chromatin nucleolus (*N. 2*), so that here there would be six bivalent chromosomes.

COREIDÆ.

13. *Anasa tristis* De G.

Twenty-one testes of this species were studied.

In regard to the chromosomal numbers my observations confirm those of Paulmier.

In the rest stage of the spermatogonium (Pl. II, Figs. 72, 73) there are two chromatin nucleoli (*N. 2*), which are much smaller than the true nucleoli (*N*) to which they are generally apposed. They have definite irregularly rounded or oval outlines as examined with Hermann's saffranine-gentian violet stain, and are not "hazy" or "indefinite" as Paulmier (1899) described. Both may be attached to the same nucleolus, or they may be joined to separate nucleoli. Sometimes each one may separate into two pieces (as is the case with one in Fig. 72). They are best seen on iron hæmatoxylin preparations so strongly destained that the chromatin reticulum does not appear.

In the monaster stage of the spermatogonia (Fig. 74) are twenty-two chromatin segments, namely, twenty larger chromosomes and two much smaller chromatin nucleoli (*N. 2*).

In the synapsis stage the twenty chromosomes unite to form ten bivalent ones, and the two chromatin nucleoli to form one bivalent one. The latter is clearly bipartite in the synapsis, but later shows an oval outline (Fig. 75); it is peripheral in position, often contains a central clearer vacuole as in the *Pentatomidæ*, and is as a rule separated from the true nucleolus (*N*).

In the monaster stage of the first maturation division (pole view, Fig. 76) are found eleven bivalent, dumbbell-shaped chromatin segments, of which the central, smallest one is the chromatin nucleolus (*N. 2*). I am able to confirm Paulmier's (1899) account of the two maturation divisions.

14. *Anasa armigera* Say

One testis of this species was studied.

The spermatogenesis seems to be very similar to that of the preceding species, but as I had no preparation stained with saffranine-gentian violet I was unable to determine the relations of the chromatin nucleoli in the rest stage of the spermatogonia.

Fig. 77, Pl. II, shows a pole view of a monaster stage of the spermatogonia, with twenty chromosomes and two chromatin nucleoli (*N. 2*); it is very similar to the corresponding stage in *Anasa tristis* (Fig. 74).

In the synapsis are formed ten bivalent chromosomes and one bivalent chromatin nucleolus.

In the monaster of the first maturation division (Fig. 78) are ten bivalent chromo-

somes and one bivalent chromatin nucleolus; Fig. 78 is a pole view, but in it those elements which appear dumbbell-shaped are seen from the side.

15. *Anasa* sp.

Of this undetermined species, which was collected for me at Berryessa in California I examined nine testes.

The resting spermatogonium shows two chromatin nucleoli (Pl. II, Fig. 79, *N. 2*) which are comparatively large and rather loose in texture, generally irregular in outline, occasionally attached to the true nucleolus (*N*), and more or less central in position.

In the monaster stage of the spermatogonia (Fig. 80) are twenty-two chromatin segments, namely, twenty larger chromosomes and two smaller chromatin nucleoli (*N. 2*).

In the synapsis the chromosomes unite to form ten bivalent ones, and the chromatin nucleoli to form one bivalent one. In the rest stage of the spermatocytes (Fig. 81) the chromatin nucleolus (*N. 2*) is seen to be somewhat elongate in form, is peripheral in position, and not attached to the true nucleolus (*N*).

In the monaster stage of the first maturation division are eleven bivalent elements, of which the smallest is the chromatin nucleolus (*N. 2*, Fig. 82); in this figure we do not have strictly pole views of all the chromosomes.

Fig. 83 shows four of the bivalent chromosomes on lateral view, in a paratongential section of a cell in the stage of the first maturation monaster. It is given here because it is the clearest case I have noticed in any Hemipteron of the quadripartite nature of these chromosomes, for while the transverse split may generally be seen at this stage, the longitudinal split is generally hidden. The poles of the spindle (not in the plane of this section, but seen in the next one to it) are situated at the upper and lower portions of the figure respectively; and it is hardly necessary to add that the first maturation division coincides with the plane of the transverse split, the second with the plane of the longitudinal split.

16. *Metapodius terminalis* Dall.

Eleven testes were studied of this species, which is very favorable on account of the large size of the cells; one should examine testes from individuals taken in June or early July, before the time of copulation.

In the rest stage of the spermatogonia (Pl. II, Fig. 84) are two chromatin nucleoli (*N. 2*) of very small size and smooth outlines, generally close together on the surface of a true nucleolus (*N*).

In the spermatogonic monaster (Fig. 85) are twenty-two chromatin segments, of which the two smallest are chromatin nucleoli (*N. 2*) and easily recognizable,

In the synapsis the twenty chromosomes unite to form ten bivalent ones, and the two chromatin nucleoli to form one bivalent one. The latter is in later stages of the growth period bilobed (*N. 2*, Fig. 86), is peripheral in position and not opposed to the larger true nucleolus (*N*).

In the monaster stage of the first maturation division are eleven chromatin segments (Fig. 87), of which the smallest, centrally placed one is the chromatin nucleolus (*N. 2*); all these elements are bivalent and on lateral view they all show the dumbbell-shape.

17. *Chariesterus antennator* Fabr.

Two testes of this form were examined.

In the rest stage of the spermatogonia I could not be certain of the presence of chromatin nucleoli, for my preparations were not very well stained to demonstrate them. There were also no spermatogonic monasters favorable enough for determining the number of chromosomes.

In the synapsis stage there is a bivalent chromatin nucleolus, but sometimes its component parts are widely separated.

In the telophase of the spermatocytes (Pl. II, Fig. 88) the chromatin nucleolus (*N. 2*) is peripheral in position, sometimes its two univalent components still separated (but that is not the case in Fig. 88). The true nucleolus (*N*) is sometimes central, sometimes peripheral in position, and occasionally it is apposed to the chromatin nucleolus.

In the monaster of the first maturation division (Fig. 89, lateral view; Fig. 90, pole view) are found thirteen chromatin segments, of which the smallest, centrally placed one is the bivalent chromatin nucleolus (*N. 2*). Of the twelve chromosomes at least eleven would seem to be bivalent (having the characteristic dumbbell-shape); but in the lateral view here given (Fig. 89), it will be noted that the chromosome nearest the left-hand side does not appear dumbbell-shaped. This may be a bivalent one seen obliquely, or it may be a univalent one; which is the case I cannot determine, since there were few satisfactory lateral views on the preparations and since the number of chromosomes in the spermatogonia could not be determined.

18. *Alydus pilosulus* H. S.

Four testes of this species were studied.

The chromatin nucleoli in the rest stage of the spermatogonia (*N. 2*, Fig. 91, Pl. II) are two in number and rounded; they are very small, usually close together, and may be or not be attached to the true nucleolus (*N*).

In the spermatogonic monaster stage (Fig. 92) are fourteen chromatin segments, two

of which, easily distinguishable from the others by their small size, are chromatin nucleoli (*N. 2*).

In the synapsis stage the twelve chromosomes unite to form six bivalent ones, and the two chromatin nucleoli to form one bivalent one. In the late stages of the growth period (Figs. 93, 94) the chromatin nucleolus (*N. 2*) is rounded and peripheral in position, and usually apposed to the true nucleolus; even when they are separated the latter is usually peripheral (*N*, Fig. 94)—an unusual position for it in spermatocytes of *Hemiptera*.

In the monaster stage of the first maturation division (Fig. 95) are seven elements, namely, six bivalent chromosomes and one bivalent chromatin nucleolus (the smallest of the seven elements, *N. 2*); all these are dumbbell-shaped on lateral view, and though Fig. 95 is a pole view of the spindle two of its chromosomes are seen from the side.

19. *Alydus eurinus* Say

One testis of this species was studied.

In the rest stage of the spermatogonia I could not determine chromatin nucleoli, probably on account of their small size.

Numerous monaster stages of spermatogonia were examined, and all showed thirteen chromatin elements (Pl. III, Fig. 96); two of these which are readily recognizable from the others by their minute size are chromatin nucleoli (the two small granules shown in Fig. 96); the eleven large elements are chromosomes, and have mostly an elongated form.

In the synapsis the two chromatin nucleoli unite to form one bivalent one, which in the telophase of the spermatocytes (*N. 2*, Fig. 97) is relatively small, peripheral in position, and quite frequently apposed to the larger true nucleolus (*N*). Of the eleven univalent chromosomes derived from the spermatogonium, ten unite to form five bivalent pairs, while one (the eleventh) does not unite with any of the others but remains univalent.

In the first maturation division are found seven chromatin elements (Fig. 98, pole view); the smallest of these is bivalent, dumbbell-shaped, and is the chromatin nucleolus (*N. 2*); the six larger elements are chromosomes. Now a careful study of numerous monaster stages seen on lateral view shows that only five of these chromosomes are dumbbell-shaped, and so bivalent on analogy with what is known for the other *Hemiptera*; while one of them is never dumbbell-shaped, approximately half the volume of the others, and is univalent. Fig. 99 is a lateral view of the spindle of the first maturation division, showing three of the five dumbbell-shaped chromosomes and (most to the right) the univalent chromosome. In all cases where the chromosome plates of this stage can

be seen on lateral view, one chromosome is always found to be of about half the size of the others and not dumbbell-shaped; on pole views this chromosome can be distinguished by its lesser depth.

So in *Alydus eurinus* there is an uneven number of chromosomes in the spermatogonia, namely, eleven; the reduction in number is effected then in the synapsis by ten combining to form five bivalent ones, while one remains univalent and uncombined, because there is no mate with which it can unite.

In the monaster of the second maturation division there are either six or seven chromatin elements. In Fig. 100 of this stage are shown seven, of which the smallest is probably the chromatin nucleolus, five are halves of the originally bivalent chromosomes and one probably the half of the originally univalent chromosome.

In the spermatid we find either six (Fig. 102) or five (Fig. 101) chromatin elements of approximately equal volume. Now these elements are too large to be derivatives of the chromatin nucleolus of the spermatocyte of the first order (*N. 2*, Fig. 98), so that the five or six elements of the spermatids would not seem to represent portions of this chromatin nucleolus; very probably the latter is so small in the spermatids or generally so closely applied to the surface of one of the chromosomes that it escapes observation. If we then eliminate the possibility of any of the elements shown in the spermatids (Figs. 101, 102) representing chromatin nucleoli or their derivatives, then we must conclude that the five or six elements here are chromosomes. But why is their number sometimes five, in other cases six? Now we know that in all other *Hemiptera* in which attention has been given to this point that each spermatid receives one-quarter of each of the bivalent chromosomes present in the spermatocyte of the first order. Accordingly it would be probable by analogy that in *Alydus eurinus* the spermatid receives one-quarter of each of the original five bivalent chromosomes. Then in the case of Fig. 101 all five elements would be such derivatives; in Fig. 102, five of the six elements. The sixth element of Fig. 102 is then probably the original univalent chromosomes of the first maturation division, which in either the first or the second maturation division could not have been divided, but must have passed undivided into one of the daughter cells; this would explain why sometimes there are only five, sometimes six chromosomes in the spermatid, for, as I have explained, none of the elements of Figs. 101 and 102 can be regarded as chromatin nucleoli.

Of course the preceding is only an attempt at a right interpretation; I have not been able to follow the univalent chromosome with precision in regard to its behavior in the maturation divisions.

20. *Corizus lateralis* Say

Four testes of this species were studied.

I could not determine whether there are chromatin nucleoli in the rest stage of the

spermatogonia, and none of the cases of spermatogonic monasters in my preparations were sufficiently favorable to allow accurate counting of the chromatin elements.

In the growth period of the spermatocytes a comparatively small, bivalent chromatin nucleolus, which in the rest stage (*N. 2*, Fig. 103, Pl. III) has a peripheral position and rounded form and is not apposed to the true nucleolus (*N*). Besides this chromatin nucleolus one or two much smaller, rounded ones can sometimes be seen in the nuclei of the resting spermatocytes, and these stain like the large one with the double stain of Hermann.

In the monaster stage of the first maturation division are always found at least seven chromatin elements; when there are eight the eighth is a small granule (Fig. 105, the smaller of the bodies marked *N. 2*), and this small element, which frequently cannot be seen at this stage, probably represents one of the minute chromatin nucleoli of the growth period. Of the seven larger elements the smallest, centrally placed one is the bivalent chromatin nucleolus (*N. 2*, Fig. 104, and the larger of the elements marked *N. 2* in Fig. 105); this chromatin nucleolus often has its component halves separated (except for a joining linin band) before the period of metakinesis (Fig. 106). The remaining six elements are chromosomes, and of them four are of approximately equal volume, while one is always much larger and one always much smaller than these four (pole views Figs. 104, 105, lateral view Fig. 106). The five largest chromosomes are clearly dumbbell-shaped on lateral view, and accordingly by analogy with the corresponding elements of other *Hemiptera* may be considered bivalent, even though the number in the spermatogonia was not determined. But the smallest chromosome puzzled me at first with regard to its valence, for it is not more than half the volume of the other five, and sometimes it does not appear dumbbell-shaped, so that I considered the possibility of its being univalent; but a careful study of it in numerous cells of the first maturation division resulted in showing in a number of clear cases that it is transversely constricted even before it becomes arranged in the plane of the equator, so that there can hardly be a doubt as to its being bivalent. Fig. 106 shows such a case in an oblique lateral view of the spindle before the chromosomes have become arranged all in one plane, with a well-marked constriction of the smallest chromosome.

The first maturation division is a reduction division and always halves the six chromosomes and the bivalent chromatin nucleolus.

21. *Harmostes reflexulus* Stal.

Thirteen testes of this species were studied.

In the rest stage of the spermatogonia there are two rounded chromatin nucleoli (*N. 2*, Fig. 107, Pl. III), of which one or both may be apposed to the true nucleolus (*N*).

In the monaster stage of the spermatogonic divisions can always be counted thirteen chromatin segments on favorable pole views—*i. e.*, in such cases where these elements can be seen all in one plane, and where they are not too closely apposed to one another (Figs. 108–110). Two of these elements are always distinguishable from the others by their smaller size and rounded shape, and these are the chromatin nucleoli (*N. 2*); they may lie close together (Fig. 110), but more usually are more separated in position (Figs. 108, 109). The remaining eleven elements, which are of large size and elongate form, are chromosomes. There can be no doubt that this is the actual number of these chromosomes, for no exceptions to it were found, and in fourteen clear cases from four different testes the number eleven was obtained with great clearness; these chromosomes are larger than the spermatogonic chromosomes of any other Hemipteron examined. Sometimes one or more of the chromosomes may show a slight transverse constriction, but this is not a constant appearance.

In the synapsis the two chromatin nucleoli derived from the spermatogonium unite to form one bivalent one; in the rest stage (which is very complete) of the spermatocyte it is elongate (*N. 2*, Fig. 111), peripheral in position and not attached to the true nucleolus; the latter is larger (*N*, Fig. 111), frequently peripheral in position, and sometimes two true nucleoli are present.

During the synapsis stage ten of the eleven chromosomes join to form five bivalent chromosomes, while the eleventh remains univalent, as will become evident from the following description:

In the first maturation division are found either seven chromatin elements or eight chromatin elements; these two conditions may be described successively.

When there are seven elements (Fig. 112 pole view of the monaster stage, Fig. 113 lateral view) one may always be distinguished by its smaller size and central position, and by its history from the rest stage of the spermatocyte to the stage under discussion this is found to be the chromatin nucleolus (*N. 2*); this we have already learned to be bivalent, and in Fig. 113 its univalent components are seen to be separating. The six larger elements are chromosomes. Five of these, as Fig. 113 shows, are clearly dumbbell-shaped and bivalent. The sixth, however (*x*), never shows a dumbbell shape before the metakinesis, but is always distinguishable from the others by its oval form. From these appearances we must conclude that this sixth chromosome is univalent—represents the odd, eleventh, chromosome of the spermatogonic monaster stage, which had no mate with which to unite during the following synapsis stage. It was in this species that I first found spermatogonia with an uneven number of chromosomes, so that I first concluded they must be abnormal cases, for heretofore in all objects the spermatogonic (normal) number has been described as an even one; I immediately sectioned testes of other

individuals to determine this point, but, as has been already stated, in the four of the thirteen testes which contained spermatogonic divisions exactly eleven chromosomes were found to be always present. Obviously all of the eleven chromosomes cannot unite into pairs during the synapsis, one must remain unmated, and this must be necessarily that one of the first maturation division which does not appear bipartite.

Now in those cases where there are eight chromatin elements present in the spermatocytes the question becomes more complicated (Figs. 114–116). Here, as in the cases where there are seven elements, one is central in position and distinguishable from the others by its smaller volume, namely, the bivalent chromatin nucleolus (*N. 2*, Figs. 114–116, in the last figure its univalent components separated); the remaining seven elements are then chromosomes. As the lateral view, Fig. 116, of the spindle shows, four of these are bivalent (the ones not marked by lettering). One (*x*) is oval in form, showing no constriction or splitting, and so is probably comparable to the univalent chromosome of those cells which contain but seven chromatin elements (*i. e.*, to *x* in Fig. 113.) There then remain the two elements marked *a* in Fig. 116, and each of these I conclude must be a univalent chromosome, which in cases where there are only seven chromatin elements in the spindle would have combined with the other to form one bivalent chromosome; if this be so, then the transverse constriction of the left-hand chromosome marked *a* in Fig. 116 would not be the line of separation between two univalent chromosomes. Another reason for looking upon these two chromosomes as univalent, is because they are of approximately the same volume as the chromosome marked *x*, which we have shown to be univalent by comparison with the chromosome *x* of Fig. 113. But there is a still better reason for considering the elements *a* of Fig. 116 to be univalent chromosomes. A pole view of a corresponding stage with eight chromatin elements shows the seven chromosomes frequently equidistant from one another (as in Fig. 115). But often we find on pole view two of the seven chromosomes close together and connected by a band of linin (*a*, Fig. 114); the two together constitute a virtual bivalent chromosome, which, however, differs from the other bivalent ones in having its long axis parallel to the plane of the equator of the spindle. Let the band of linin which connects these chromosomes *a* become stretched out, and as a result we would have a bivalent chromosome lying parallel to the plane of the equator, and with its univalent halves widely separated—*i. e.*, the condition that maintains for the chromosomes *a* of Fig. 116.

To summarize, we find two conditions in the spermatocytes: (1) there are seven chromatin elements, namely, one bivalent chromatin nucleolus, five bivalent chromosomes, and one univalent chromosome; and (2) eight chromatin elements, namely, one bivalent chromatin nucleolus, four bivalent chromosomes, one univalent chromosome (corresponding to that of condition 1), and two other univalent chromosomes (which

together would correspond to the fifth bivalent chromosome of condition 1). To determine which of these conditions is the more usual, I counted the number of chromatin elements seen on pole views of the monaster stage of the first maturation division. These counts were made on spermatocytes from five different testes, and may be condensed into the following table:

PREPARATION NO.	EIGHT ELEMENTS.	SEVEN ELEMENTS.
86	4	33
238	6	12
408	2	1
410	1	9
356	0	23
Total =	13	78

Thus those spermatocytes with seven chromatin elements would seem to be the more frequent condition. In both cases there is one univalent chromosome, which represents the odd chromosome of the spermatogonia; but why in cells of the second condition two chromosomes should remain separated instead of combining to form a bivalent one, as they do in the first condition, I cannot explain, unless perhaps the presence of the odd univalent chromosome may in some way disturb the union into pairs of the ten other chromosomes during the synapsis.

In those cases where there are seven chromatin elements in the equator of the first maturation spindle, the metakinesis results in the division of all the elements; this is a reduction (transverse) division of the bivalent chromatin nucleolus and of the five bivalent chromosomes, but in what plane the univalent chromosome divides could not be determined. Only one case was seen where the univalent chromosome was left undivided in the equator after the daughter elements of the six other elements had reached opposite poles of the spindle. Thus it would seem that in this division, in the cases where there are seven elements present, all the elements become divided; how it is in the cases where there are eight elements could not be determined. In the spermatid are found either six chromosomes (Fig. 117) and one chromatin nucleolus (*N. 2*), or five chromosomes and one chromatin nucleolus. This would show that the chromatin nucleolus and five chromosomes (the derivatives of the original five bivalent ones) divide in the second maturation division, but that the sixth chromosome, the derivative of the originally univalent one, does not divide but passes undivided into one of the two spermatids. Thus the valence of the seven elements in these generations would be: *first spermatocyte*, one bivalent chromatin nucleolus, five bivalent chromosomes, one univalent chromosome;

second spermatocyte, one univalent chromatin nucleolus, five univalent chromosomes, one semivalent chromosome; *spermatid*, one semivalent chromatin nucleolus and either five or six semivalent chromosomes.

22. *Protenor belfragei* Hagl.

Five testes of this exceedingly interesting species were studied from individuals that had just completed their last ecdysis.

In the rest stage of the spermatogonia (Pl. III, Fig. 118) are two rounded chromatin nucleoli which are usually attached to the surface of a much larger true nucleolus (*N*).

Pole views of the monaster stage of the spermatogonic mitosis show with great distinctness exactly thirteen chromatin elements (Figs. 119-123). This number was found in thirteen cells of one testis, in about sixteen cells of a second, in six cells of a third, and in two cells of a fourth—these being all the favorable cases found, and all these testes had been fixed with Flemming's fluid (the stronger mixture). The fifth testis sectioned had been fixed in picro-acetic acid, and in it the number of chromosomes could not be counted because of the swelling action which this reagent exerts upon the chromatin. These chromosomes are unusually large and on suitable preparations can be counted with exactness. In only two of the cells in which they were counted was there observed a fourteenth element; this was a minute granule (*t*, Fig. 121), which, on account of its being present so rarely in these monaster stages and on account of there being no element to represent it in the later history of the spermatogenesis, need not be taken into account; it seems to be very inconstant, and might possibly represent either a portion of chromatin which had become separated from one of the chromosomes, or a chromatin nucleolus transmitted from some distant parent and now nearly reaching disappearance.

Which two of the elements in the spermatogonic monaster represent the chromatin nucleoli of the previous rest stage I am unable to determine, but that two of them do represent these bodies there can be no doubt from what has been determined for the succeeding stages; judging by analogy with the case in all other *Coreidæ* examined, they would probably be the two smallest elements. Now Figs. 119-123 show what is to be seen very distinctly in all cases, namely, that there are three chromatin elements much larger than the ten remaining. One of these three, that designated *x* in Figs. 119-123, imposes by its relatively very large volume; this has in most cases the form shown in Figs. 120 and 121, but in a few cases it was noticeably elongated, as in Figs. 122 and 123. The last figure shows it to have a transverse constriction around the middle; and this case, together with the fact of its great volume, would show it to be equal potentially to at last two chromosomes; for purposes of description we shall call this the "chromosome *x*." The two other chromosomes, which can always be recognized by their relatively

large volume, are those designated by the letter *k* in Figs. 119–123; these two are of approximately equal volume, and each has about half the volume of the chromosome *x*.

There are accordingly present in the spermatogonic monaster thirteen chromatin elements, of which two (probably the smallest) represent the chromatin nucleoli; of the eleven chromosomes, three are much larger than the others, namely, the one marked *x* and the two marked *k* in the Figs. 119–123. In the metakinesis all these elements are halved longitudinally.

In the following synapsis stage we find a small chromatin nucleolus composed of two parts, which in every way is comparable to the bivalent chromatin nucleolus of the growth period of other *Coreidæ*; this is marked *N. 2* in Figs. 124, 129, 130. This chromatin nucleolus is peripheral in position, and only occasionally has a true nucleolus apposed to it (Fig. 130). Generally its two univalent halves are not closely apposed but more or less separated, often widely separated (*N. 2*, Fig. 131), but the two always come close together to form a dumbbell-shaped, bivalent body before the monaster stage of the first maturation division. Certainly its two components must represent the two univalent chromatin nucleoli of the rest stage of the spermatogonia (*N. 2*, Fig. 118).

During the synapsis stage also ten out of the eleven chromosomes derived from the spermatogonium combine to form five bivalent chromosomes, as will be shown in treating of the maturation divisions. The odd one of the eleven chromosomes does not combine with any other during the synapsis stage, and this is the largest of the chromosomes of the spermatogonium, namely, the chromosome *x*. This element has a remarkable history in the growth period. Through the whole growth period it acts like a chromatin nucleolus in preserving a compact form and in continuing to take the saffranine stain with the use of the double stain of Hermann, while the other chromosomes take the violet stain. It will be remembered that this chromosome *x* becomes distinguishable first in the spermatogonic mitoses (Figs. 119–123), while in the preceding spermatogonic rest stage it cannot be distinguished, for then it takes the violet stain like the other chromosomes and takes part in the formation of the nuclear reticulum just as they do; accordingly it can be concluded that it commences to behave differently from the other chromosomes at the beginning of the growth period of the spermatocyte. In the early synapsis (Fig. 124) it has the same general shape as in the spermatogonic monaster stage (compare the element marked *x* in Fig. 124 with the corresponding one in Figs. 120, 121), but it has greatly increased in volume, as a comparison of these figures show, since it will be recalled that the chromosome *x* of the spermatocytes is a half of the chromosome *x* of the spermatogonia. Later in the growth period the chromosome *x* elongates into the form of a bent rod (Figs. 125–130), which usually lies close to the nuclear membrane (in this point also resembling a chromatin nucleolus); throughout the growth period it keeps its com-

pact structure and smooth outline. When it is beginning to elongate a faintly-marked clear line can be seen in its long axis (Figs. 125, 129), and this is evidently a longitudinal split, comparable to that of the bivalent chromosomes; this split cannot be seen in the telophase nor at any period of the maturation divisions. About coincidentally appears a transverse split; this may be a simple annular constriction, or a clear connecting bridge of linin (as in Fig. 128). This transverse constriction, pointing to a bipartite nature, would show that the chromosome x is bivalent; but it must have been already bivalent in the spermatogonia (where also a transverse constriction can sometimes be seen, Fig. 123), for it does not unite with any other chromosome in the spermatocytes. I can find no other explanation for its occasional bipartite appearance during the synapsis.

In the later period of the synapsis stage, in the telophase, and in the early prophases of the first maturation division the chromosome x undergoes considerable changes in form. The slightly bent rod (Figs. 125, 129) of the early synapsis bends at its middle point, where the transverse constriction was apparent, into the form of a U or V (Figs. 126, 127, 130), or even the form of an S (Fig. 127*b*). The end result of these bendings seems always to be a horseshoe-shape (Fig. 130) or a nearly closed ring (Fig. 127*c*). From the early synapsis stage until the beginning of the prophases of the first maturation mitosis a true nucleolus of varying form is attached to the surface of the chromosome x (N , Figs. 124, 125, 127–130); occasionally this true nucleolus may be separated into two or three parts, all of them attached to the chromosome. In the prophases of the first maturation division the nucleolus becomes detached from the chromosome, rapidly decreases in size, and becomes lost before the nuclear membrane disappears.

In the early prophases of the first maturation division (Figs. 131, 132) are found the following elements: (1) five bivalent chromosomes, of which all five are shown in Fig. 132, only four in Fig. 131 (all these seen on lateral view); all these show at this stage a well-marked longitudinal split (often of circular or oval outline) and a transverse split (which marks the point of union of two univalent chromosomes); the mode of formation of these elements is very similar to that described by Paulmier (1899) for *Anasa*. (2) The bivalent chromatin nucleolus, the two parts of which may be in close contact (N , 2, Fig. 132) or may still be widely separated (N , 2, Fig. 131). And (3) the large chromosome x , the largest of all the elements, which now has decreased somewhat in volume owing to the greater condensation of its substance; seen from the side, it gives the appearance of a thick horseshoe or a nearly closed ring (x , Fig. 131). Of the five bivalent chromosomes, one is always much larger than the others (K , 2, Figs. 131, 132), and this was evidently formed by the union of the two large chromosomes K of the spermatogonic mitoses (Figs. 119–123).

In the later prophases (Figs. 133, 134) the five bivalent chromosomes condense into the form of dumbbells or sometimes of rings, the large chromosome *K. 2* (Fig. 133) passing through these stages more slowly than the others, so that it often retains loose texture and roughened outlines after the four others have become compact with smooth outlines. The bivalent chromatin nucleolus now has its univalent components generally in rather close apposition (*N. 2*, Figs. 133, 134). The chromosome *x* is very compact in structure, and when seen from the side has squarish form (*x*, Fig. 133), an indentation at one end of which marks the point of apposition of the ends of the primitive horseshoe form—which latter in some cases (Fig. 134) may still be seen at this late stage. Usually the chromosome *x* is longer than broad, and the clear line sometimes found in its long axis does not then represent the primitive longitudinal split, of which there seems no trace at this stage, but the space separating the two arms of the horseshoe.

In the monaster stage of the first maturation mitosis (Figs. 135–137) there are accordingly seven elements (in the cell from which Fig. 136 was drawn, one of the bivalent chromosomes lay out of the plane of the section). These are the bivalent chromatin nucleolus (*N. 2*), the smallest of all; the chromosome *x* (*x*), the largest of all; and five bivalent chromosomes, of which one is almost always recognizable by its greater volume (*K. 2*), and this is the bivalent chromosome formed by the synapsis of the two larger chromosomes *K* of the spermatogonia. The five bivalent chromosomes and the chromatin nucleolus become divided transversely in the metakinesis (reduction division). The chromosome *x* (for successive stages in its division, Figs. 136, 138), which has its long axis coinciding with the plane of the equator, becomes divided into two along its median axis. This would appear at first sight to be a longitudinal (equational) division; but it is not, for we have learned that this peculiar chromosome had first the form of a straight rod, which then bent at its middle point into a U or V, then the arms of the U or V laid themselves parallel to and close together, so that a division along the median axis results now in the separation of these arms, and is accordingly a reduction division.

A view of the second spermatocyte, before its chromatin elements have definitely arranged themselves in the plane of the equator of the spindle, shows also seven elements (Fig. 139): one univalent chromatin nucleolus (*N. 2*); one chromosome larger than the others, a half of the original chromosome *x* ($x \frac{1}{2}$); and five univalent chromosomes, one (*K*) larger than the others and directly comparable to one of the large chromosomes *K* of the spermatogonia. In the metakinesis following (Fig. 140) the five univalent chromosomes are divided equationally, and the univalent chromatin nucleolus (*N. 2*) is also divided (but in what plane was not determined). The chromosome $x \frac{1}{2}$, however, never becomes divided in this mitosis, but passes undivided into one of the daughter cells (Fig.

140); and in the dyaster stage of the second maturation division (Fig. 141) we see in each daughter cell (spermatid) the chromosomes densely apposed, forming together a rounded, irregular mass, and in only one of the two daughter cells the chromosome $x^{\frac{1}{2}}$.

The reduction of the number of chromatin elements in *Protenor belfragei* is accordingly as follows: *Spermatogonium*, two univalent chromatin nucleoli, ten univalent chromosomes, one chromosome x ; *first spermatocyte*, one bivalent chromatin nucleolus, five bivalent chromosomes, one chromosome x ; *second spermatocyte*, one univalent chromatin nucleolus, five univalent chromosomes, one-half chromosome x ; *spermatid*, one semivalent chromatin nucleolus, five semivalent chromosomes, and either present or absent one-half chromosome x . This chromosome x is the odd one of the spermatogonia; it does not unite with any other one in the synapsis stage of the spermatocyte, yet since it sometimes appears bipartite in the synapsis and undergoes a transverse division in the first maturation mitosis, it may perhaps be looked upon as bivalent in both spermatogonium and spermatocyte. If this is a correct conclusion, then the uneven number of chromosomes in the spermatogonia would be the result of two univalent ones remaining there united instead of separating—this compound, bivalent one being the chromosome x . This chromosome, as we have seen, behaves in the rest stage of the spermatogonia like the other chromosomes, but in the growth period of the spermatocytes it acts in many ways like a chromatin nucleolus.

LYGÆIDÆ.

23. *Cymus augustatus* Stal.

Six testes of this species were studied.

There was no material at my service fixed with Flemming's or Hermann's fluids, so not being able to use the triple stain of Hermann I was unable to determine the relations of the chromatin nucleoli in the rest stage of the spermatogonia. The preparations also showed no favorable cells for counting the chromosomes in this generation.

In the synapsis stage there is a rather small, dumbbell-shaped, and so probably bivalent, chromatin nucleolus, which becomes spherical in the following (complete) rest stage of the spermatocyte.

There were no pole views of the chromosomal plate of the first maturation division, but two pole views of the succeeding dyaster are here given (Pl. IV, Fig. 143, showing the chromosomes before taking their definite position in the spindle, while in Fig. 144 they occupy this position and are seen from their ends); here can be counted twelve chromosomes and one smaller body (*N. 2*, probably the chromatin nucleolus, very small in Fig. 144). On lateral views of the first maturation monaster (Fig. 142, which, however, shows only nine of the elements), all the chromosomes usually appear dumbbell-

shaped, and so would be bivalent. Sometimes one of them appears rounded or oval instead of dumbbell-shaped; this may be a bivalent one seen obliquely, or it might possibly be a univalent one; the lack of knowledge of the spermatogonic number does not permit us to decide which.

24. *Ichnodemus falicus* Say

Five testes of this species were studied.

Chromatin nucleoli were not determined in the rest stage of the spermatogonia. But they are very probably present there because two small rounded ones can be seen in the late spermatogonic prophases; whether more than two I could not determine. All the testes examined had been fixed with picro-acetic acid, causing such a swelling and consequent juxtaposition of the chromosomes that in only one case were they sufficiently separated to be counted (Pl. IV, Fig. 145), and here fourteen chromatin elements were present. Since in the first maturation spindle there are always seven bivalent chromosomes, I should think that the fourteen elements of Fig. 145 are univalent chromosomes, and that in this monaster the chromatin nucleoli are hidden.

In the monaster stage of the first maturation division are seen on pole views (Figs. 147, 148) always seven larger elements, which on lateral view are found to be all dumbbell-shaped, and so are probably bivalent. All these seven elements are presumably chromosomes corresponding to the fourteen found in the spermatogonia (Fig. 145). Besides these are to be seen at this stage, and also in the preceding prophases (Fig. 146), two or three smaller elements, which are presumably chromatin nucleoli. Generally three of these are found (*N. 2*, Figs. 146, 147), and generally the case is as in Fig. 146, two larger and one smaller. The two larger being generally of approximately equal volume (Figs. 146, 148), it is quite probable that taken together they may represent one bivalent chromatin nucleolus with separated components. The smaller one sometimes appears transversely constricted, as in Fig. 146, so this one may also be bivalent; if this is the case, then there should be four univalent ones in the spermatogonia. But the number of them could not be determined in the spermatogonia, and in the growth period of the spermatocytes the stain was not favorable for showing their relations.

25. *Peliopelta abbreviata* Uhl.

Five testes of this species were studied.

In a pole view of the spermatogonic monaster (Pl. IV, Fig. 149, the only clear case observed) are found sixteen chromatin segments, ten of which are larger and more elongate than the others, while six are rounded and smaller. The two smallest (*N. 2*) are probably chromatin nucleoli, by analogy with other species of the *Lygaeidæ*.

In the growth period of the spermatocytes there is one clearly bivalent chromatin nucleolus, which is frequently apposed to the larger true nucleolus.

In the monaster stage of the first maturation division (Fig. 150, pole view) there are eight elements, the smallest of which is the chromatin nucleolus (*N. 2*); on lateral view all these elements appear dumbbell-shaped and hence are bivalent (Fig. 151). Of the seven chromosomes of this stage, two are very small and five much larger, the two small ones in Fig. 151 being designated as *a. 2* and *b. 2*, while in the figure only three of the large ones are shown. Apparently the two small chromosomes of the spermatocyte correspond to the four small chromosomes of the spermatogonium; thus the bivalent chromosomes *a. 2* and *b. 2* of Fig. 151 would correspond respectively to the univalent chromosomes *a* and *b* of Fig. 149, and the five large bivalent chromosomes of the spermatocyte to the ten large univalent ones of the spermatogonium. It is very evident that in the synapsis stage one of the small univalent chromosomes derived from the spermatogonium never unites with one of the large, for the two univalent components of each small bivalent chromosome of the spermatocyte have approximately the same volume. This speaks, of course, very strongly for the maintenance of the individuality of the chromosomes during these generations.

26. *Edanocala dorsalis* Say

Four testes of this species were studied.

In the rest stage of the spermatogonium are present two chromatin nucleoli of rounded form (*N. 2*, Fig. 152, Pl. IV); these are sometimes attached to one another, sometimes to the true nucleolus (*N*).

In the spermatogonic monaster there are thirteen chromatin elements present, exactly this number being found in all of nine clear cases. Two of these, which are rounded and much smaller than the others, are the chromatin nucleoli (*N. 2*, Figs. 153, 154); the remaining eleven elements are relatively large, elongated chromosomes. All these elements are halved in the metakinesis.

In the synapsis stage the two chromatin nucleoli combine to form one bivalent one, and even up to the rest stage of the spermatocyte (Fig. 155) it remains dumbbell-shaped, with a bridge of linin connecting its univalent components; it is attached to the surface of the true nucleolus (*N*, Fig. 155), and the "double nucleolus" so formed usually lies close to the nuclear membrane.

In the first maturation division there are seven chromatin elements (Fig. 156, pole view of monaster stage), of which the smallest, usually centrally placed one is the bivalent chromatin nucleolus (*N. 2*). Of the six chromosomes, five, when seen on lateral view, are dumbbell-shaped, and so bivalent; but the sixth is oval in outline without any

transverse constriction, about the size of a univalent component of one of the bivalent chromosomes. This is the chromosome marked *x* in Fig. 157; in this figure is shown also the chromatin nucleolus (*N. 2*), but only two of the five bivalent chromosomes. This sixth small chromosome is univalent and unipartite, and evidently is the odd, eleventh, chromosome of the spermatogonium, which had no fellow to combine with during the synapsis. It is always recognizable on lateral views (Fig. 157) by its peculiar volume and form, and even on pole views of the chromosomal plane is recognizable by its lesser depth (Fig. 156, *x*).

The first maturation division halves all seven elements (Fig. 158, anaphase), being a transverse (reducing) division of the five bivalent chromosomes and of the chromatin nucleolus, but in what plane the univalent chromosome (*x*) divides could not be determined on account of its nearly spherical form. Apparently also in the second maturation division all the six chromosomes become divided, since in the spermatid six chromatin elements can frequently be counted; but I am not certain that the sixth chromosome does become divided in this mitosis.

The reduction in the number of chromosomes for this species is accordingly: *Spermatogonium*, two univalent chromatin nucleoli, eleven univalent chromosomes; *first spermatocyte*, one bivalent chromatin nucleolus, five bivalent chromosomes, one univalent chromosome; *second spermatocyte*, one univalent chromatin nucleolus, five univalent chromosomes, one semivalent chromosome.

27. *Oncopeltus fasciatus* Dall.

Eight testes of this species were studied.

The rest stage of the spermatogonium (Pl. IV, Fig. 159) shows usually one comparatively large, elongate chromatin nucleolus (*N. 2*), which is generally peripheral in position; this apparently represents two joined end to end, for sometimes two separate ones can be seen.

In the spermatogonic monaster there are sixteen chromatin elements (Fig. 160). Fourteen are chromosomes and two are chromatin nucleoli, as the relations in the spermatocyte mitoses will demonstrate. But it is difficult to determine which two are the chromatin nucleoli, all sixteen elements being of approximately equal size, though, judging by analogy with the other species of the family, they are probably the smallest two (*N. 2*, Fig. 160).

In the synapsis the fourteen chromosomes unite to form seven bivalent ones. But there is never any very close union of the two chromatin nucleoli, and in the rest stage of the spermatocytes the following conditions are found: (1) the chromatin nucleoli apposed to one another and to the true nucleolus (Fig. 161); (2) apposed to one

another, but separated from the nucleolus (Fig. 162); (3) the chromatin nucleoli separate from one another, and only one in contact with the nucleolus (Figs. 163, 165); (4) the chromatin nucleoli separate from one another and from the nucleolus; (5) the chromatin nucleoli separate from one another, but both attached to the nucleolus (Fig. 164). These conditions do not appear to be stages in position, but rather individual variations. Whenever the two chromatin nucleoli are mutually apposed, it is never an intimate apposition—*i. e.*, they never fuse to form one large rounded one such as is the general rule in the *Pentatomidæ*. Through the rest stage of the spermatocytes each chromatin nucleolus remains elongate (they appear round only when seen from the end). Sometimes each shows a trace of a transverse constriction, and in one case (Fig. 165) one of them was separated into two parts.

Through the prophases of the first maturation mitosis the chromatin nucleoli remain separate from one another, and each is elongate in form (Fig. 166, *N. 2*, showing also all seven bivalent chromosomes on lateral view).

Pole views of the monaster stage of the first maturation division show in most cases nine chromatin elements (Fig. 167); the seven larger ones are chromosomes, all bivalent and on lateral view dumbbell-shaped (Fig. 166); the two smaller, centrally placed ones are the two chromatin nucleoli (*N. 2*, Fig. 167). In one case, ten elements were seen on pole view (Fig. 168); this is very unusual, but it may probably be explained by the assumption that there are here two chromatin nucleoli, six bivalent chromosomes, and two univalent chromosomes formed by the precocious separation of the parts of a bivalent chromosome. A lateral view of the spindle is given (Fig. 169), showing the two chromatin nucleoli, but only two of the seven bivalent chromosomes.

In the metaphase of this mitosis all seven chromosomes become transversely divided (reduction division), and each of the chromatin nucleoli becomes also divided in a plane perpendicular to its long axis (compare Figs. 169 and 170, in each of which only two of the seven chromosomes are shown). A pole view of one cell of the dyaster stage following (Fig. 171) shows the two daughter chromatin nucleoli (*N. 2*) and the seven daughter (univalent) chromosomes (the apparent transverse constrictions on them representing the reappearance of the original longitudinal split; compare the left-hand chromosome of Fig. 170).

The behavior of the chromatin nucleoli is thus different from that of the other *Hemiptera* examined in the following regards: (1) their large size in the spermatogonic monaster (Fig. 160), so that they can hardly be distinguished in volume from the chromosomes; (2) the phenomenon that they remain more or less separate from one another during the growth period of the spermatocytes (Figs. 161–165) and prophases of the first maturation division (Fig. 166); (3) the fact that one or both may appear

bipartite in the growth period (Fig. 165); and (4) the fact that they remain separate from one another in the first maturation division, and that each divides transversely (Figs. 167, 169, 170, *N. 2*). The last mentioned point deserves particular consideration, for a transverse division of a chromatin element in the *Hemiptera* always means a reduction division—*i. e.*, a separation of two whole univalent components of one already bivalent element. From these facts we are led to the conclusion that here the chromatin nucleoli are virtually bivalent in the spermatogonia, and that since the spermatogonic division gives a longitudinal half of each of them to the spermatocytes, that each is already bivalent in the spermatocytes—a bivalence then produced before the synapsis stage of the growth period. This conclusion would explain all their peculiarities listed above. In the spermatogonium accordingly there would be virtually four chromatin nucleoli, twice the number found in the other species of the *Lygaeidae* (with possibly the exception of the not fully explained *Ichnodemus falicus*).

CAPSIDÆ.

28. *Leptopterna dolabrata* Linn.

Three testes of this species were studied.

There were no spermatogonia on any preparations (taken from adults in the last instar before copulation).

In the rest stage of the growth period of the spermatocytes are found the following relations for the chromatin nucleoli: There are two chromatin nucleoli, which (1) are attached to one another but separate from the true nucleolus (Plate IV, Fig. 172); (2) they are attached together and to the true nucleolus (Fig. 173); (3) they are separated from one another but both attached to the true nucleolus (Fig. 175), often at opposite poles of the latter (Fig. 174). In almost all cases they are attached to the true nucleolus, so that Fig. 172 represents an unusual case. Each chromatin nucleolus is probably a univalent one, for it never shows a bipartite appearance and is usually rounded, so that in Figs. 172 and 173 the two together would constitute one bivalent chromatin one; but there cannot be certainty on this point until the number in the spermatogonia is determined.

Pole views of the monaster stage of the first maturation division (Fig. 176) show seventeen chromatin elements, one of which, centrally placed, is always much larger than the others. On lateral view all appear dumbbell-shaped and so are probably bivalent. Probably one of these elements represents the bivalent chromatin nucleolus described for the growth period, then the sixteen remaining would be chromosomes.

29. *Calocoris rapidus* Say

Three testes of this species were studied.

The number of chromatin nucleoli in the rest stage of the spermatogonia was not determined.

In the most favorable pole view of a spermatogonic monaster were counted about thirty chromatin elements (Plate IV, Fig. 177), but these elements were densely grouped so that I could not be positive as to the exact number. Since there are in the spermatocytes fourteen bivalent chromosomes, two bivalent chromatin nucleoli and one that is probably univalent, there would be probably in the spermatogonia twenty-eight univalent chromosomes and five univalent chromatin nucleoli, a total of thirty-three elements.

In the telophase and rest stages of the spermatocytes there is a large true nucleolus, which is remarkable in being flattened against the nuclear membrane (*N*, Figs. 178, 179); it appears sickle-shaped on cross section, and has irregularly lobular outlines on surface view. In these stages there are five small chromatin nucleoli (*N. 2*, Fig. 178); one of these is larger than the others and always spherical in form (the larger one of Figs. 178 and 179), and since it never appears bipartite is presumably univalent; it is frequently attached to the true nucleolus. The four other chromatin nucleoli are arranged in two pairs, the two components of a pair being connected by a band of linin (Figs. 178, 180, only one of the pairs shown in Fig. 179). Each one of these four is very small and spherical, and accordingly probably univalent, and each pair would then be bivalent. Thus there would appear to be in the spermatocytes one larger univalent chromatin nucleolus and two bivalent ones, in each of the latter the univalent components being not closely apposed.

Pole views of the monaster stage of the first maturation division show always sixteen chromatin elements (Figs. 185, 186). Three of these are always distinguishable by their much smaller size (*N. 2*, Figs. 185, 186). These three probably represent the three chromatin nucleoli of the preceding growth period; two of them appear dumbbell-shaped on lateral view (Fig. 181, and one of the two is shown in Fig. 184), obviously representing the two bivalent ones of the growth period; while the third one always appears rounded and never dumbbell-shaped (Fig. 181, the lowest of the elements designated *N. 2*), and on lateral view of the spindle lies nearer one pole of the spindle than the other (*N. 2* Fig. 183), this one obviously representing the univalent chromatin nucleolus of the growth period. Figs. 181–184 represent oblique lateral views of the spindles, so that in each case only one spindle pole is shown, such oblique views giving the best views of the chromatin elements. The thirteen remaining larger elements of the first spermatocytes are chromosomes, and lateral views show that twelve of these are dumbbell-shaped and hence probably bivalent; but the thirteenth is quadrivalent, composed of two bivalent (dumbbell-

shaped) placed side by side with their long axes parallel. This quadrivalent chromosome shows its nature plainly on lateral view (*t*, Figs. 182, 183); on pole view it may always be told by its greater volume (*t*, Figs. 185, 186), sometimes even on pole view it appears slightly constricted (Fig. 186, *t*), the constriction then denoting the plane of apposition of the two bivalent chromosomes of which it is composed; it is placed in the spindle so that the transverse constriction of each of its component chromosomes lies in the plane of the equator (Figs. 182, 183).

There are accordingly in the first spermatocyte two bivalent chromatin nucleoli, one univalent chromatin nucleolus, twelve bivalent chromosomes, and one quadrivalent chromosome, in all sixteen chromatin elements.

In the spindle of the second spermatocyte are found either fifteen chromatin elements (Fig. 188) or sixteen (Fig. 187). This disparity in number is produced by the univalent chromatin nucleolus not dividing in the first maturation mitosis but passing undivided into one of the two daughter cells (second spermatocytes), for it will be remembered that in the monaster stage of the first mitosis it always lies a little outside of the plane of the equator, nearer one pole of the spindle than the other (Fig. 183, *N. 2*). The rest of the chromatin elements of the second spermatocyte are univalent halves of those in the first spermatocyte (the first maturation division is a reduction division), namely, halves of the two bivalent chromatin nucleoli, of the twelve bivalent chromosomes, and of the one quadrivalent chromosome. The latter element can be recognized in the second spermatocytes by its greater size (*t*, Figs. 187, 188), and it here consists of two univalent chromosomes placed in apposition; in the spindle of the first maturation mitosis (Figs. 182, 183) it was so placed that each of its bivalent chromosomes underwent a transverse (reduction) division, just as was the case with the other bivalent chromosomes.

30. *Pæcilocapsus lineatus* Fabr.

Six testes of this species were studied.

There were no spermatogonic mitoses on my preparations, and I could not determine the relations of the chromatin nucleoli in the rest stage of the spermatogonia.

In the rest stage of the spermatocytes are found two chromatin nucleoli (*N. 2*, Fig. 189, Pl. IV); in one testis two additional, very minute chromatin nucleoli seemed to be present, but I could not find them on the other preparations. One of the chromatin nucleoli is very large and clearly bilobed (Fig. 189) so that it would seem to be bivalent; the other is considerably smaller and apparently always rounded, so that it may be univalent. These two chromatin nucleoli are sometimes, but not usually, in mutual contact.

Pole views of the monaster stage of the first maturation mitosis show always eighteen chromatin elements (Fig. 190). One of these is much smaller and one much larger than

the others. Probably two of the eighteen elements correspond to the two chromatin nucleoli of the growth period, but I cannot determine which two they are; if this is so, then there would be here sixteen chromosomes (all apparently bivalent judging from their dumbbell-shape on lateral view), and one bivalent and one univalent chromatin nucleolus. But there can be no surety in regard to these valences without a knowledge of the numbers in the spermatogonia.

31. *Pæcilocapsus goniphorus* Say

Four testes of this species were studied.

There were no spermatogonic mitoses on my preparations (all from adult individuals).

In the rest stage of the spermatocytes there are present four bipartite chromatin nucleoli (*N. 2*, Figs. 192–195, Pl. V), in one single case there were five (Fig. 191). The largest of the four is composed generally of two rods placed side by side (this is shown in lateral view in Figs. 191, 194, in end view in Figs. 192, 193, 195); the lateral view of this one (the lower of the large ones of Fig. 191) sometimes shows that each of its component rods may be transversely constricted, which might imply that each of the rods is bivalent and hence that the whole is quadrivalent. In each of the three small bipartite chromatin nucleoli the univalent components may be closely apposed to one another (Figs. 191, 192), or may be more or less widely separated (Figs. 193–195). Of the four chromatin nucleoli the largest and the smallest are generally attached to opposite poles of the true nucleolus (*N. 2*, Figs. 191–194), though the relative positions vary considerably as shown by the figures; and it is the two which are generally not so attached which have their component parts most widely separated.

Thus there are at least four, possibly five, bivalent chromatin nucleoli in the spermatocytes.

Pole views of the monaster stage of the first maturation mitosis show either seventeen chromatin elements of approximately equal volume (Fig. 197), and this was the rule in two of the testes examined; while in a third testis in the majority of cases there was present a smaller element in addition to the seventeen larger ones (*t*, Fig. 196); possibly this small element may always be present, but frequently escape observation by being closely apposed to one of the larger elements. All these elements appear dumbbell-shaped on lateral view (Fig. 198), and so are probably bivalent.

How many of these eighteen elements are chromosomes and how many are chromatin nucleoli I cannot determine, since the number in the spermatogonia was not ascertained. Possibly the small element (*t* of Fig. 196) may represent the largest chromatin nucleolus of the preceding growth period, and the seventeen remaining be chromosomes; or if all four chromatin nucleoli are represented in the first maturation division, then there would remain fourteen chromosomes.

PHYMATIDÆ.

32. *Phymata* sp. (*P. wolffi* Stal.?).

Nine testes of this species were studied.

In the rest stage of the spermatogonium there are two chromatin nucleoli (*N. 2*, Fig. 199, Pl. V), usually unequal in size; frequently one or both of them is in contact with the true nucleolus (*N*).

In the spermatogonic monaster are seen on pole view (Fig. 200) thirty chromatin elements; two of these certainly represent the chromatin nucleoli, but they offer no peculiarities by which they can be distinguished from the twenty-eight small chromosomes.

In the synapsis stage the twenty-eight chromosomes unite to form fourteen bivalent ones, and the two chromatin nucleoli to form one bivalent one. The latter is in the telophase and rest stage of the spermatocyte (Fig. 201) clearly transversely constricted, showing its bipartite nature, and is always apposed to the surface of the larger true nucleolus (Fig. 201, *N*).

Pole views of the monaster stage of the first maturation division (Fig. 202) always show exactly fifteen chromatin elements, namely, fourteen chromosomes and one chromatin nucleolus. All these elements are found to be dumbbell-shaped on lateral view (Fig. 203, showing eight of them), so that all are bivalent. The chromatin nucleolus cannot be distinguished in size from the chromosomes.

NABIDÆ.

33. *Coriscus ferus* Linn.

Three testes of this species were studied.

The relations of the chromatin nucleoli were not determined in the small nuclei of the spermatogonia, and the spermatogonic mitoses were not favorable for counting the small, rounded chromosomes.

In the growth period of the spermatocytes there is usually one large bivalent chromatin nucleolus, with its component parts in close apposition (*N. 2*, Fig. 205, Pl. V), attached to the true nucleolus (*N*). Sometimes its component parts (which are of equal volume) are separated from one another, and then both may be attached to the same true nucleolus (Fig. 204), or they may be apposed to separate nucleoli, or only one of them may be apposed to a nucleolus (of which there are generally two, sometimes three). Besides the large, bivalent chromatin nucleolus can be seen in most nuclei a much smaller chromatin nucleolus (Fig. 205) which stains like the larger one; it is generally close to the nuclear membrane, but is occasionally apposed to a true nucleolus.

In the first maturation division there are ten chromatin elements (Fig. 206, in which

five are seen on lateral view and five on pole view, all these elements not having taken their definite position in the equator of the spindle). All are bivalent, as is proved by their bipartite appearance on lateral view. One of them is smaller than the others, and may represent the large (bivalent) chromatin nucleolus of the growth period (*N. 2*, Fig. 206), while the nine remaining elements are probably chromosomes; if this interpretation be correct then the small (univalent?) chromatin nucleolus found in the growth period would not be represented in the first maturation division.

REDUVIIDÆ.

34. *Acholla multispinosa* De G.

Eight testes of this species were studied.

The relations of the minute chromatin nucleoli could not be determined in the rest stage of the spermatogonia.

In the most favorable pole view of a spermatogonic monaster (Pl. V, Fig. 207) could be counted thirty-one chromatin elements. The twenty-four larger elements seen here are univalent chromosomes, the seven smallest are chromatin nucleoli (some of them very minute). Of the latter there are six arranged in three pairs and one that is isolated. Now we shall find that in the spermatocytes there are four bivalent chromatin nucleoli (Figs. 208–211), so that in the spermatogonia there should be eight; and accordingly though only seven are to be seen in Fig. 207, we are justified in concluding that an eighth must be present there but hidden from view by one of the chromosomes. Thus there would be in the spermatogonium in all probability twenty-four chromosomes and eight chromatin nucleoli, in all thirty-two elements.

In the synapsis stage of the growth period the twenty-four chromosomes unite to form twelve bivalent ones. The eight chromatin nucleoli likewise combine to form four bivalent ones, which near the close of the growth period (Figs. 208, 209) are seen to be small bodies attached to the surface of the true nucleolus (*N*). Each is dumbbell-shaped, usually with its component univalent parts in close apposition, but occasionally the latter are more or less separated from one another.

Pole views of the monaster stage of the first maturation division (Fig. 210) show sixteen elements, namely, twelve larger, bivalent chromosomes (dumbbell-shaped on lateral view) and four much smaller chromatin nucleoli (*N. 2*). All these elements are halved in the following metakinesis, which is a transverse (reduction) division, and pole views of the daughter cells (second spermatocytes, Fig. 211) show twelve larger, univalent chromosomes and four smaller, univalent chromatin nucleoli (*N. 2*).

35. *Sinea diadema* Fabr.

Two testes of this species were studied.

The relations of the chromatin nucleoli in the rest stage of the spermatogonia could not be determined.

There were on my preparations only a few spermatogonic monaster stages, and none of these were favorable for determining the number of chromosomes; the chromosomes are small, densely grouped, and particularly minute elements among them might be chromatin nucleoli.

In the rest stage of the spermatocyte are present four small chromatin nucleoli (*N. 2*, Figs. 212, 213, Pl. V), all of them attached to the surface of a large true nucleolus (*N.*). One is larger than the others, and appearing on lateral view to be always transversely constricted (Fig. 213) is probably bivalent; and as one of the three smaller ones is sometimes found to be bipartite, this too would be bivalent. The two remaining are apparently always spherical and not transversely constricted, so that they would seem to be univalent. If this interpretation is correct, there would be here two bivalent chromatin nucleoli each with its component parts closely apposed, and one bivalent one with its components separated, that is three bivalent ones in all; and in the first maturation division there are three chromatin nucleoli present (Figs. 214, 215), which would corroborate this conclusion. But since it could not be determined how many there are in the spermatogonia, the relations in the spermatocytes cannot be considered positively demonstrated.

Pole views of the monaster stage of the first maturation division (Figs. 214, 215) show always three minute chromatin elements, which are chromatin nucleoli (*N. 2*), and apparently thirteen larger chromosomes. But a careful examination of these larger elements shows that in every case four bivalent chromosomes form together a plurivalent one, all four being closely apposed and with their long axes parallel to one another. This is best seen on lateral view of the spindle (Figs. 217, 218), where the four chromosomes marked *t* are always found to be grouped close together; in Fig. 216 only these four chromosomes with their mantle fibre attachments are seen on lateral view. Of the four chromosomes thus grouped together, the two middle ones stand in the closest apposition (Fig. 216–218); and on pole views these two middle ones may be so closely apposed as to appear as one long one (*t*, Fig. 214), or a slight transverse constriction marks the division line between them (*t*, Fig. 215). It follows accordingly that the three elements seen on pole view and marked *t* are really four bivalent chromosomes, the two central ones being so closely apposed as to appear generally as one long one. A comparison of the elements designated *t* in Figs. 214 and 215 with the corresponding elements in Figs. 216–218 makes this evident. Accordingly there are really fourteen bivalent (dumbbell-shaped)

chromosomes present, four of which are always grouped together to form a particular group.

The metakinesis halves each of the fourteen bivalent chromosomes transversely (reduction division, Figs. 217, 218), but the four which together form the group that has been described divide later than the others, as can be seen from the figures given; and it is at this metaphase that this group of four can be most easily recognized. Such a group of four closely united bivalent chromosomes has not been found by me in any other Hemipteron.

36. *Prionidus cristatus* Linn.

Four testes of this species were studied.

In the rest stage of the spermatogonium there are apparently five chromatin nucleoli (*N. 2*, Figs. 220–222, Pl. V), two of which are generally considerably larger than the others, and some or all of which may be attached to the true nucleolus (*N*, Figs. 221, 222). But it is difficult to be sure of the exact number, for sometimes not more than four can be seen (Fig. 221).

In the spermatogonic monaster on pole views (Figs. 223, 224) are seen twenty-six chromatin elements, three of which (*N. 2*) are always much smaller and (by analogy with the other species of the *Reduviidæ*) would probably represent the three small chromatin nucleoli of the preceding rest stage. Two of the twenty-six chromatin elements are elongate in form and much larger than the others; these may be chromosomes (which would be more probable), or they might represent the large chromatin nucleoli of the rest stage of the spermatogonium. If there are really five chromatin nucleoli in the spermatogonia, then there would be these five elements and twenty-one chromosomes present in the spermatogonic mitosis. In five pole views I could count exactly twenty-six chromatin elements, in two there were either twenty-six or twenty-seven, and in one either twenty-four or twenty-five; but in all these cases three particularly small and two particularly large elements could be distinguished.

In the rest stage of the spermatocyte (Fig. 225) are found four chromatin nucleoli (*N. 2*) attached to the true nucleolus (*N*). One of these is longer than the others and rod-shaped, and may represent the two larger chromatin nucleoli of the spermatogonium joined into one bivalent one; the three smaller ones may appear rounded or slightly elongate, and these may represent the three small chromatin nucleoli of the spermatogonium; occasionally two of the small ones are apposed together.

There were no maturation mitoses on my preparations (from adults taken in the month of September).

37. *Milyas cinctus* Fabr.

In the single testis of this species studied (an individual of the month of September) there were no mitoses.

In the rest stage of the spermatocytes (Figs. 226–228) are found one long, rod-shaped chromatin nucleolus and two or three smaller ones ($N. 2$), all apposed to the true nucleolus (N). The long one is certainly bivalent, since it frequently shows a transverse constriction (Fig. 228) or is bent at the middle point (Fig. 227); on account of the length of each of its component parts it might be concluded that each of them is bivalent—*i. e.*, that the whole element is quadrivalent—but neither of the parts appear bipartite, so that this long chromatin nucleolus would more probably be bivalent. In those cases where only two smaller chromatin nucleoli are present (Fig. 228), each of them is clearly transversely constricted (bipartite) and hence bivalent; where three are present we find that one is bipartite and accordingly bivalent (Fig. 227), the other two are spherical and hence univalent. By comparing Figs. 227 and 228 we find that the two spherical chromatin nucleoli of the former would together represent one of the small bivalent chromatin nucleoli of the latter. Thus we may conclude that there are three bivalent chromatin nucleoli present in these spermatocytes, though the two components of one of them may be separated.

LIMNOBATIDÆ.

38. *Limnobates lineata* Say.

Of this small species I was able to procure the testes of only one (adult) individual. The only stages of spermatogenesis present were spermatocytes in the growth period.

In the large spermatocytes in the rest stage (Pl. V, Fig. 219) is found a large chromatin nucleolus ($N. 2$), usually apposed to the true nucleolus (N) in such a manner that the chromatin nucleolus touches with one pole the nuclear membrane, with the other the true nucleolus.

HYDROBATIDÆ.

39. *Hygotrechus* sp.

Twelve testes were studied of this species (from the vicinity of Philadelphia).

The relations of the chromatin nucleoli in the rest stage of the spermatogonia could not be determined, since the nuclei are very small at this stage.

The spermatogonic monaster shows on pole view (Pl. V, Fig. 229) exactly twenty chromatin elements, of which the eighteen largest are chromosomes and the two smallest ($N. 2$) probably chromatin nucleoli.

In the synapsis stage of the spermatocyte (Fig. 230) are seen two small chromatin

nucleoli (*N. 2*), which are not closely apposed; the true nucleolus (*N*) is much larger. In the rest stage the chromatin nucleoli are usually widely separated from one another, and on account of their small size are difficult to discover. In the growth period they do not stain bright red with the saffranine-gentian violet stain of Hermann, but deep violet, even on excellently stained preparations. Such a staining reaction as this I have not found for the chromatin nucleoli of other *Hemiptera*, for in all the other forms examined the chromatin nucleoli take the red saffranine stain intensely even while the chromosomes have taken the violet stain (in the rest stage). Perhaps in *Hygotrechus* the chromatin nucleoli differ chemically less from the chromosomes than in the other *Hemiptera*, and undergo in the growth period changes parallel to those of the chromosomes.

Pole views of the monaster stage of the first maturation division (Fig. 231) show always exactly eleven chromatin elements. On account of the number in the spermatogonia (twenty), I would interpret these as nine bivalent chromosomes, and two univalent chromatin nucleoli which are not combined into one bivalent one. This is very probable, since the two univalent chromatin nucleoli are often widely separated in the growth period; and on lateral views of the monaster stage of the first maturation division, there are found two bodies which are spherical and not dumbbell-shaped. On no lateral view of this monaster stage could I see all the nine chromosomes clearly; but in one case I saw eight of them, all clearly dumbbell-shaped (bipartite), so that probably all nine are bivalent. The first maturation division is reductional, as in the other *Hemiptera*.

40. *Limnotrechus marginatus* Say

Two testes of this species were studied.

There were no spermatogonic monaster stages present, and I could not determine the relations of the chromatin nucleoli in the rest stage of these cells.

In the rest stage of the spermatocyte (Pl. V, Fig. 232) is found a large true nucleolus (*N*), and separated from it, usually close to the nuclear membrane, a rounded chromatin nucleolus (*N. 2*).

Pole views of the first maturation monaster (Fig. 233) show eleven chromatin elements; sometimes one appears much smaller than the others, and it may represent the chromatin nucleolus.

NAUCORIDÆ.

41. *Pelocoris femorata* Pal. Beauv.

Fourteen testes of this species were studied from adult and half-grown individuals of different seasons of the year. There were an abundance of rest stages of spermatogonia and of spermatocytes in the growth period, but no maturation mitoses present.

The chromosomes were counted in a number of pole views of the monaster stage of the spermatogonia, but in most cases they were so densely grouped as to make the numbers obtained very uncertain. In the most favorable case (Pl. V, Fig. 234) apparently twenty chromatin elements are present, but I could not be certain of this number.

The relations of the chromatin nucleoli in the growth period are very puzzling. On preparations stained with Hermann's saffranine-gentian violet, there appear to be a variable number of rounded bodies of different volume which stain bright red; sometimes they are arranged in pairs, sometimes in long chains, sometimes they show no regular arrangement whatsoever. One nuclear body, much larger than the others and generally irregular in outline, may be a true nucleolus. If all the red-staining bodies are chromatin nucleoli, they would seem to be present in an unusually large number in this species. A study of further material will be necessary to explain the nature and relations of these bodies.

BELOSTOMATIDÆ.

42. *Zaitha* sp.

There are two species of this genus known in the vicinity of Philadelphia where I collected my material, namely, *Z. fluminea* Say and *Z. aurantiacum* (Leidy), but which species it was that I collected I omitted at the time to determine. Ten testes were examined.*

In the rest stage of the spermatogonium (Fig. 235) are present two small chromatin nucleoli (*N. 2*) apposed to a large true nucleolus (*N*).

Pole views of the spermatogenic monaster stage (Figs. 236, 237) show twenty-four chromatin elements, of which the smallest two (*N. 2*) represent the chromatin nucleoli, and the remaining twenty-two are chromosomes. Of the chromosomes, four are always elongate and much larger than the others (*t*, Figs. 236, 237).

In the synopsis stage of the growth period the twenty-two chromosomes unite to form eleven bivalent ones. In the rest stage of the spermatocytes there are two univalent chromatin nucleoli, sometimes joined to make a bivalent one, attached to the surface of the true nucleolus.

Pole views of the monaster stage of the first maturation division (Fig. 238) show

* In my "Note on the Genital Organs of *Zaitha*" (*American Naturalist*, Vol. xxxiv, 1900). I described the structure of these testes. To the text figure B given in that paper, I would add now that the earlier stages of spermatogenesis are to be found in what I called the "terminal fibres" at the proximal end of the testis, these fibres being five long and much convoluted slender tubes which interlace together and form a rounded whitish mass at the extreme proximal end of the testis; they were not correctly represented in the figure cited. In adult individuals it is only in this portion of the testis that the earlier spermatogenetic stages occur, all the rest of the testis being filled with spermatozoa. It is necessary to collect individuals in the month of May (shortly before the copulation), in order to obtain the stages of the maturation divisions.

always thirteen chromatin elements. Two of these are much smaller than the others (*N. 2*), and are obviously the univalent chromatin nucleoli, which at this stage do not make up a bivalent one. The eleven large elements are chromosomes, and since all of them appear dumbbell-shaped on lateral view, they are all bivalent. Two of the eleven chromosomes have a markedly greater volume than the others (*t 2*, Fig. 238), and these correspond to the four large chromosomes of the spermatogonia (*t*, Figs. 236, 237); that is to say, in the synapsis the four large chromosomes derived from the spermatogonia unite together to form two bivalent ones, and a large one never appears to unite with a small one.

The first maturation mitosis is a reduction division, and each daughter cell (second spermatocyte) receives eleven whole univalent chromosomes.

III. GENERAL CONCLUSIONS.

1. *The process of spermatogenesis in the Hemiptera, and the individuality of the chromosomes.*

In the *Hemiptera heteroptera* we find, as generally elsewhere in the *Metazoa*, a number of generations of spermatogonia in each of which all the chromatin elements are halved in metakinesis (apparently in all cases equationally), the last generation producing spermatocytes of the first order. These spermatocytes enter upon a growth period of long duration, which is followed by the first maturation division, resulting in the formation of spermatocytes of the second order; and in the second maturation division the spermatocytes of the second order are divided into spermatids. There are always exactly two maturation divisions and no more. The metamorphosis of the spermatids into the spermatozoa has not been studied by me, and has not the broad comparative interest of the preceding stages, but it has been described by Henking (1890) and Paulmier (1899).

The growth period of the spermatocytes is of the greatest interest, for here are a remarkable series of changes not found in any other generation of the germ cells nor, so far as is known, in any somatic cells. And the most important of these changes are found in the synapsis stage of the growth period. The synapsis stage is well-marked in all the *Hemiptera* examined by me without exception, characterized by a dense grouping of the chromatin loops; the citations given by me in my study on *Peripatus* (1901) show that it seems to be present in almost all, if not all the *Metazoa* in which the spermatogenesis and ovogenesis has been carefully examined. The dense grouping of the chromosomes in this stage is not an artifact produced by faulty fixation methods, as McClung (1900) has recently maintained, for exactly the same appearances are to be

found after the action of most diverse fixatives. The dense and interlacing grouping of the chromosomes that is so characteristic for the synapsis of Insects, Copepods, *Ascaris* and some other forms, is, however, not found in all; thus it does not appear to occur in *Salamandra* (Meves, 1896).

Moore (1895) first gave the name "synaptic phase" to that stage in the growth period of Elasmobranchs when the reduction in the number of the chromosomes takes place. Accordingly, the criterion of the synapsis stage is first of all the combination of univalent chromosomes to form bivalent ones; whether the chromosomes are then densely grouped or not is of secondary importance. A special chapter of the present paper is given to the broader significance of this stage.

In all the *Hemiptera* examined, and also in *Peripatus*, I have found that bivalent chromosomes are formed in the synapsis by a union, end to end, of every two univalent chromosomes. All other writers on this stage, with the exception of Brauer, have been unable to determine how the univalent chromosomes become united together; Brauer's (1893 b) careful study of the growth period in the spermatogenesis of *Ascaris* rendered it very probable that it is a union end to end, but his figures do not prove it absolutely. Certain writers state that the reduction of the number in chromosomes is effected by the chromatin spirem segmenting into only half the normal number of chromosomes. This is, however, an incorrect statement, inasmuch as the reduction in number is occasioned in some cases (*Hemiptera*, *Peripatus*) before the "spirem" stage of the first maturation division, and inasmuch as in most cases, if not all, there is no continuous *chromatin* spirem found at any time during the growth period and prophases of the first maturation mitosis.

Accordingly in the *Hemiptera* the reduction in number of the chromosomes is effected in the synapsis stage, a long while before the maturation divisions, by a union end to end of every two chromosomes. During the synapsis stage the chromosomes become split longitudinally, as was first shown by Paulmier (1898, 1899) for *Anasa*—a process that I had overlooked in my former paper (1898). Each bivalent chromosome is thus both transversely and longitudinally split before the maturation mitoses, the transverse split represented by the band of linin joining the approximated ends of the two univalent chromosomes.

At the close of the growth period there is a well-defined rest stage in most *Hemiptera*, when chromosomal boundaries are practically indistinguishable; but in the *Coreidae* and *Reduviidae* there appears to be no such stage, and accordingly such a stage would appear to have no broad significance.

In the early prophases of the maturation divisions the chromosomes are bivalent but quadripartite, each one being transversely and longitudinally split; in the later pro-

phases, up to the monaster stage of the first mitosis, the longitudinal split generally closes temporarily. The definitive form of these chromosomes in all the *Hemiptera* examined is that of a dumbbell which may be either straight or bent; ring forms are more infrequent, but are occasionally found in all species. In the *Hemiptera*, as in *Peripatus*, each ring may be conceived as a dumbbell which has become bent until its ends meet, and accordingly the hollow of the ring is not the longitudinal split, but a space separating the univalent chromosomes. That is to say, generally only one end of one univalent chromosome is joined to one end of the other, but in the ring form both ends of the one are joined with both ends of the other. In all bivalent chromosomes that have not the ring form a longitudinal axis can be plainly determined, and generally each univalent chromosome is elongated in the same line; the constriction perpendicular to this long axis is a true transverse division, and is the band of linin joining the ends of the two univalent chromosomes. This orientation of the axes of the bivalent chromosomes allows the positive determination of the manner in which the chromosomes are halved in the maturation divisions.

In the first maturation division in all the *Hemiptera* examined the bivalent chromosomes are transversely divided, *i. e.*, whole univalent chromosomes are separated; in the anaphase of this division the longitudinal split of the univalent chromosomes reappears, and in the second maturation mitosis the univalent chromosomes are halved through the plane of this split (equation division). The valences of the chromosomes in the successive generations are accordingly: *spermatogonium*, univalent; *first spermatocyte*, bivalent; *second spermatocyte*, univalent; *spermatid*, semivalent. The classing of the chromosomes as semivalent in the spermatid may appear surprising, for they have always been considered univalent; but they must be considered semivalent with reference to the number in the spermatogonia in those cases, as in all the *Hemiptera* examined, where the second maturation division follows immediately upon the first without any indication of an intermediate rest stage.

Thus in the *Hemiptera*, as in *Peripatus*, the maturation divisions do not accomplish the reduction in number of the chromosomes, for this takes place long before in the growth period; the first maturation division separates entire univalent chromosomes (*pseudoreduction*, Rückert, 1894), the second halves each univalent chromosome equationally, and thus halves the chromatin mass. Though the chromosomes of the spermatid are logically semivalent with reference to those in the spermatogonia, yet they are potentially univalent on account of the increase in mass of the chromatin during the growth period (where at least a doubling of the mass occurs).

In my study on *Peripatus* (1901) it was shown that the individuality of the chromosomes is maintained from the last spermatogonic mitosis up to and through the maturation

divisions; and in that paper I have referred to the observations of other workers corroborative of the individuality of the chromosomes, so that they need not be recalled here. In such *Hemiptera* as the *Coreidæ* there is no true rest stage in the growth period, so that definite chromosomal outlines can be determined throughout the growth period. And even in those *Hemiptera* where a rest stage does occur in this period, in which the chromosomes become reticular and practically indistinguishable from one another, all evidence renders it probable that the chromosomal individuality is retained through this period—*i. e.*, that a particular univalent chromosome of the maturation mitosis represents a particular one of the spermatogonia. This evidence is as follows: The chromatin nucleoli, which are only modified chromosomes, retain their compact form and so are readily distinguishable throughout all periods of these generations. Then in those cases where there is an uneven number of chromosomes in the spermatogonia, and the odd one remains univalent in the spermatocytes, this odd one can always be distinguished in the maturation mitoses. Then where two of the spermatogenic chromosomes are particularly large, there is always found in the first maturation mitosis one particularly large bivalent chromosome which can only correspond to those two. Further, after a rest stage there is always the same number of chromosomes as were present before that rest stage. All this evidence speaks for a chromosome of a spermatogonium corresponding to a chromosome of a spermatocyte; and if in these generations there is a maintenance of chromosomal individuality, there is a probability that there is such a maintenance through all generations of the germinal cycle. But this conclusion by no means implies that a chromosome of one generation is actually the same as a chromosome of another. For we know that each chromosome is halved in an equational division, and that each daughter chromosome so produced must increase to a volume equal to that of the mother chromosome before it enters upon a second mitosis. Thus new substance must continually be elaborated by the chromosomes during the rest stages, and in the course of this elaboration the old substance of the chromosome and its physical form are correspondingly changed. There is no evidence that chromosomal substance remains unchanged from generation to generation, for all evidence shows that it undergoes metabolic change and growth in the rest stages. But nevertheless it seems very probable that a chromosome of one generation is a derivative of a particular chromosome of the preceding generation, and that the chromosomes may thus be said to maintain themselves as entities through successive generations.

There are many cases where chromosomal boundaries are indistinguishable in the rest stages, so that in such cases it has been argued that the chromosomes show no individuality. But these are negative examples, and positive cases that speak for the maintenance of the chromosomal individuality must be considered as the decisive ones. No

other assumption can so well explain the maintenance of a constant number. The fact that the chromosomes build up new substance at one stage, and give off waste products at another, does not invalidate our conclusion. Those who deny the maintenance of chromosomal individuality, on the basis of a study of objects where the chromosomes do not appear to be continuous from generation to generation, are not justified in concluding that there is never a maintenance of the individuality until they have examined the positive cases. And since there have been shown to be positive cases, we must conclude (1) either that in all normal mitoses of the germinal cycle the chromosomal individuality is maintained, or (2) that it is preserved in some cases but not in others. The fact that it has been demonstrated for some cases renders it probable that it is maintained in all cases, even though it cannot be demonstrated in all.

2. *The chromatin nucleoli.*

The term "chromatin nucleolus" was applied by me (1898) to the remarkable chromatin element, in form like a nucleolus but in behavior and staining reactions like a chromosome, in the nuclei of spermatocytes of *Euchistus* (*Pentatoma*); the name was given in order to denote this double similarity, though I fully realized that this structure was in all essentials a modified chromosome. A special monograph (1899 b) was devoted by me to the true nucleolus (plasmosome, Ogata) of Metazoan cells; and in a lecture at the Woods Holl laboratory (1898 b) I classified the other "nucleolar" structures as "karyosomes, which are merely thickened nodal points of the chromatin reticulum; further, what I shall term the 'chromatin-nucleus' [typographical error for 'chromatin nucleolus'], which is found in certain spermatocytes; and then various structures which stain neither like the true nucleolus nor the chromatin, and to which such terms as 'Paramcleoli,' 'Nebennucleoli,' and 'Pseudonucleoli' have been applied. It is one of the most difficult questions to determine the nature and correspondence of the latter structures. . . . But from the cases studied by me, it would appear that some of these structures in *Metazoa* probably must be placed within the category of true nucleoli, and be regarded as true nucleoli of a different chemical nature; . . . our criterion of nucleoli probably should not be based as much upon chemical as morphological facts."

The chromatin nucleolus is a modified chromosome, as both my earlier and the present observations show. The term may have been injudiciously chosen, since I myself showed that it has nothing in common with a true nucleolus except sometimes in the form and in containing vacuoles. In its stead McClung (1899) has given the name "accessory chromosome," and Paulmier (1899) the name "small chromosome." But McClung's term is not satisfactory in not being at all definite, and Paulmier's term is not

applicable to those cases where it is as large as the other chromosomes. Hence I consider that confusion in terminology would be best avoided by retaining my original term, "chromatin nucleolus."

In my first description of the spermatogenesis of *Euchistus* (1898 a), I stated that I could not find chromatin nucleoli in spermatogonia, and that one appeared for the first time in the spermatocyte by a metamorphosis of one of the fourteen chromosomes; this was an error that I have corrected in the present paper, for in *Euchistus*, just as Paulmier (1899) correctly described for *Anasa*, there are two chromatin nucleoli in the spermatogonium, and these unite in the spermatocyte to form one bivalent one. And in all the *Hemiptera* examined by me the larger chromatin nucleoli of the spermatocytes are derivatives of chromatin nucleoli of the spermatogonia, except the remarkable "chromosome x" of *Protenor*, to which we shall return. As far as I have been able to determine, the chromatin nucleoli are always halved in the mitoses of the spermatogonia.

(a) *General Characteristics.*

The chromatin nucleoli are morphologically chromosomes, undergoing division in mitosis like the other chromosomes, but differing from them in the rest stage by preserving a definite (usually rounded) form. There is also another difference which is of great use in their study: by the use of the double stain of Hermann, saffranine and gentian violet, the chromosomes proper stain red only in mitosis and violet in the rest stage, while the chromatin nucleoli stain red in the rest stage also, and so can be sharply distinguished from the chromatin of the chromosomes.* Thus the chromatin nucleoli of the *Hemiptera* seem to retain at all stages the stain characteristic for the substance of the chromosomes when in the height of mitosis. In the *Hemiptera* examined the true nucleoli never takes this red stain, but take the violet, so that they may in this way be easily distinguished from the chromatin nucleoli.† With iron-haematoxylin staining the chromatin nucleoli stain more intensely than the chromosomes in the rest stage; but with this stain the true nucleoli generally stain deep black like the chromatin nucleoli, so that it is far less satisfactory than the preceding method for differentiating these two structures. With the triple stain of Ehrlich-Biondi-Heidenhain, the chromatin nucleoli

* The only exception to this staining reaction was found in the spermatocytes of *Hygotrechus*, where in the rest stage the chromatin nucleoli always take the violet stain.

† However, in cells of many other *Metazoa* I have found that the true nucleoli show a particular electivity for the saffranine, so that chemical reactions are not tests for true nucleoli; nucleoli may differ chemically from one another, even in the same cell at the same stage, or at different stages, and no better case of this may be mentioned than the ovocytes of the growth period of *Gryllus*. In the *Hemiptera* the true nucleoli are generally much larger than the chromatin nucleoli, more or less irregular in outline, and they usually occupy a more or less central position in the nucleus (though I have mentioned two or three exceptions), while the chromatin nucleoli in the spermatocytes are generally in contact with the nuclear membrane.

and chromosomes in the rest stage are green, the true nucleoli red; with Delafield's hæmatoxylin and eosin, the chromatin nucleoli and chromosomes stain blue, the true nucleolus red; with both these methods the chromatin nucleoli stain more intensely than the chromosomes in the rest stage.

In the spermatogonia the chromatin nucleoli are generally small, often very minute and difficult to distinguish. They are apparently always halved in the spermatogonic mitoses, though I have not been able to determine this for all species. They always increase in volume during the growth period of the spermatocytes; the relative amount of this increase varies in different species, but it is a number of times greater than in the spermatogonia. During this increase in mass there can be found in most cases a clear vacuole in the chromatin nucleolus, so that the increase would appear to be not so much one of the proper substance of the chromatin nucleolus as of an intussusception of fluid from without; I have not figured these vacuoles in the present paper, but showed them in a preceding one (1898 a). In the prophases of the first maturation division the chromatin nucleolus decreases very considerably in volume, until when the monaster stage is reached its volume may be very little greater than in the spermatogonia. It is possible that its increase in mass during the growth period may be due in part to a decondensation of its substance, but in some part at least it is due to the above-described taking in of fluid substance from without.

In the spermatogonia they are irregular in position, sometimes close together, sometimes separated, but usually not in contact with the nuclear membrane; in these cells they are very frequently in all species apposed to the true nucleoli.* In the growth period of the spermatocytes they are more regular in position: thus they are separated from the true nucleoli and then always in contact with the nuclear membrane in *Euchistus*, *Mormidia*, *Peribalus*, *Cosmopepla*, *Nezara*, *Brochymena*, *Trichopepla*, *Eurygaster*, *Metapodius*, *Anasa*, *Chariesterus* (generally), *Corizus*, *Harmostes*, *Calocoris*, *Hygotrechus*, *Limnotrechus*; they are, as a rule, apposed to the true nucleoli in *Podisus*, *Perillus*, *Cænus*, *Alydus*, *Protenor*, *Peliopelta* (not always), *Edancala*, *Oncopeltus* (not always), *Leptopterna*, *Pæcilocapsus*, *Phymata*, *Coriscus*, the *Reduviide*, *Limnobates* and *Zaitha*. We shall refer again to the significance of this apposition. A chromatin nucleolus and a true nucleolus closely attached together constitute a "double nucleolus;" it remains to be shown whether the "double nucleoli" of certain cells of other *Metazoa*, as *e. g.* in the cells of Sertoli of *Salamandra* and *Mus*, as described by Hermann and others, may also be cases of apposed chromatin nucleoli and true nucleoli. It is very characteristic of the chromatin nucleoli of the spermatocytes in the growth period to be closely apposed to the nuclear membrane. And when they are apposed to true nucleoli,

* In the spermatogonia there are in all species an irregular number of true nucleoli, but in the spermatocytes of most of the species examined there is regularly one large one.

they retain this position if they are of comparatively large size (as in most *Pentatomidæ*) but do not when they are of comparatively small size (as particularly in the *Reduviidæ*). Now the true nucleolus is rarely in contact with the nuclear membrane when it is not apposed to a chromatin nucleolus, so that when the two are mutually apposed it appears to depend upon their relative volumes whether they will be peripheral or central in position—a very large chromatin nucleolus pulling to the periphery the true nucleolus, a small chromatin nucleolus being pulled by the true nucleolus toward the centre of the nucleus.

That the chromatin nucleoli are morphologically chromosomes is shown particularly in mitosis, when they simulate in form and divide like chromosomes; an examination of the chromatin nucleoli, designated *N. 2*, in the plates of the present paper, demonstrate this point. The univalent chromatin nucleoli of the spermatogonia generally unite to form bivalent ones in the synapsis stage just as do the chromosomes, and generally the number of them in the spermatocytes is just half of that in the spermatogonia (certain exceptions shall be considered later). In the first maturation division each bivalent chromatin nucleolus is halved transversely (reduction division) just as are the bivalent chromosomes.

Thus the chromatin nucleoli are essentially chromosomes, but chromosomes which preserve a compact form and dense structure throughout the rest period.

(b) *Number and Valence.*

It is most frequently the case that there are two univalent chromatin nucleoli in the spermatogonia, as in the *Pentatomidæ*, *Eurygaster*, *Coreidæ*, *Peliopelta*, *Ædancala*, *Phymata*, *Coriscus* (?), *Hygotrechus*, *Zaitha*. In these cases the two chromatin nucleoli join together to form one bivalent one in the growth period; but in *Euchistus tristigmus* and *Chariesterus* the two frequently remain separate in the growth period, yet this is not a complete separation for there would seem to be a linin connection between the two, since they generally become more closely approximated at the time of the first maturation division when such a linin connection may be seen. But in some of these species (*Peribalus*, *Cænus*, *Trichopepla*, *Coriscus*) besides the bivalent one are found one or two (three or four in *Trichopepla*) much smaller ones, which appear to be univalent, in the spermatocytes; whether these are represented in the spermatogonia or whether they arise in the spermatocytes for the first time, I could not determine on account of their minuteness.

In *Cymus* and *Ichnodemus* I could not determine the number in the spermatogonia, but since here there is one bivalent one in the spermatocytes, there would probably be two univalent ones in the spermatogonia. The same would probably be true for *Corizus* and *Leptopterna*.

The *Reduviidæ* and certain *Capsidæ* show a larger number of chromatin nucleoli.

Thus in *Acholla* there are eight in the spermatogonia which form four bivalent ones in the spermatocytes; in *Sinea* and *Milyas* there are three bivalent ones in the spermatocytes, and accordingly probably six in the spermatogonia; in *Prionidus* there are apparently five in the spermatogonia, two of which unite in the spermatocytes to make one bivalent one while the three others remain univalent. In *Calocoris* there are in the spermatocytes two bivalent and one univalent; in *Pæcilocapsus lineatus*, one bivalent and one apparently univalent; in *P. goniphorus* certainly four, and possibly five, bivalent chromatin nucleoli in the spermatocytes. In these forms one or more of the chromatin nucleoli may have their component parts more or less widely separated, but these separated components generally come together before the first maturation mitosis.

Bivalent chromatin nucleoli which have their components in close mutual apposition appear always to be transversely divided in the first maturation division (reduction division); for the behavior of those which are univalent I refer to the chapter on "Observations."

Oncopeltus affords the interesting case where the two chromatin nucleoli of the spermatogonia are apparently each bivalent—bivalent elements in a generation where all the chromatin elements are usually supposed to be univalent.

(c) *The Peculiar Chromosome of Protenor.*

In *Protenor*—for the details compare the description in the chapter on "Observations"—there are two chromatin nucleoli in the spermatogonia, which in the spermatocytes unite to form a bivalent one, as we have just seen to be quite generally the rule in *Hemiptera*. But the largest of the chromosomes of the spermatogonic mitoses, the "chromosome x," does not behave in the growth period of the spermatocytes like the other chromosomes, but is similar to a chromatin nucleolus in preserving a compact form and in retaining the saffranine stain. This is the odd chromosome, the eleventh, which does not combine with any other during the synapsis stage, and which cannot be distinguished in the rest stage of the spermatogonia because there it behaves exactly like the other chromosomes, and takes part in the formation of the nuclear reticulum. This is the only case in the *Hemiptera* where one chromosome becomes differentiated into a chromatin nucleolus for the first time in the spermatocyte generation, unless the minute chromatin nucleoli of *Peribalus*, *Cænus*, *Trichopepla* and *Coriscus* may be found to have a similar history.

(d) *Function.*

All the observations show that the chromatin nucleoli are modified chromosomes, which behave essentially like the chromosomes in mitosis but quite differently in the rest stage.

Paulmier (1899) has suggested that they are degenerate chromosomes. This would

seem to be true to some extent, but not wholly correct for the following reasons. In a large number of the species examined the chromatin nucleoli are regularly closely apposed to the surfaces of true nucleoli. Now it seems probable that the true nucleoli are masses of substances formed by the metabolism of the cell, probably waste substances (Montgomery, 1899 b). When we find accordingly the mutual apposition of them to chromatin nucleoli, it would be permissible to conclude that the chromatin nucleoli are chromosomes which are especially concerned with nucleolar metabolism. And this I think would be the correct interpretation. The chromatin nucleoli are in that sense degenerate, that they no longer behave like the other chromosomes in the rest stages; but they would appear to be specialized for a metabolic function. Thus it might be that in the Insects the chromatin nucleoli are those chromosomes which either exert a greater metabolic activity than the other chromosomes, or which carry out some special kind of metabolism; and from this point of view they would certainly seem to be much more than degenerate organs. As to their origin, compare the chapter on the "Number of Chromosomes."

Like the chromosomes, the number of chromatin nucleoli in the germ cells appears to be a fixed one for the species. In somatic cells they are often more numerous than in the germ cells, however, but that somatic difference will not be discussed in this paper which concerns itself with the germinal cycle.

(e) *Occurrence.*

Chromatin nucleoli were found by me in all the *Hemiptera* examined, and I have found them also in *Coleoptera* (*Harpalus*) and *Orthoptera* (*Gryllus*, *Ceuthophilus*). McClung (1899, 1900) has described them in various *Orthoptera*, in some forms of which they are larger than the chromosomes. Finally, my student, Miss Wallace (1900), has found them in the spermatogenesis of a spider (Agalenid).

Accordingly they would seem to be present in the Insects and Arachnids, but are apparently absent in the *Crustacea*, and I have shown (1901) that they are not present in *Peripatus*.

It is, however, quite possible that they will be discovered in other forms, if proper attention is paid to them. The question of their ontogenetic origin will be considered later (compare the section on the "Significance of the uneven number" of chromosomes).

3. *The Number of Chromosomes.*

The following table shows the number and valence of the chromosomes and chromatin nucleoli in the *Hemiptera* examined, all of which has been explained in detail in the chapter on "Observations." The abbreviation "*univ.*" has been employed for "univalent," and "*biv.*" for "bivalent."

SPECIES.	SPERMATOGONIA.				SPERMATOCYTES.			
	Chromosomes.		Chromatin nucleoli.		Chromosomes.		Chromatin nucleoli.	
	No.	Valence.	No.	Valence.	No.	Valence.	No.	Valence.
<i>Euchistus variolarius</i>	14	univ.	2	univ.	7	biv.	1	biv.
<i>E. tristigmus</i>	12	univ.	2	univ.	6	biv.	1 or 2	biv. or univ.
<i>Podisus spinosus</i>	14	univ.	2	univ.	7	biv.	1	biv.
<i>Mormidea lugens</i>	14	univ.	2	univ.	7	biv.	1	biv.
<i>Peribalus limbolaris</i>	14	univ.	2	univ.	7	biv.	1	biv.
<i>Cosmopepla carnifex</i>	16	univ.	2	univ.	8	biv.	1	biv.
<i>Nezara hilaris</i>	14	univ.	2	univ.				
<i>Brochymena</i> sp.....	14	univ.	2	univ.	7	biv.	1	biv.
<i>Perillus confluent</i>	14	univ.	2	univ.	7	biv.	1	biv.
<i>Cœnus delius</i>	12	univ.	2	univ.	6	biv.	2	{ 1 biv. 1 univ.
<i>Trichopepla semivittata</i>	14	univ.	2	univ.	7	biv.	4 or 5	{ 1 biv. 3 or 4 univ.
<i>Eurygaster alternatus</i>					6	biv.	1	biv.
<i>Anasa tristis</i>	20	univ.	2	univ.	10	biv.	1	biv.
<i>A. armigera</i>	20	univ.	2	univ.	10	biv.	1	biv.
<i>A. sp</i>	20	univ.	2	univ.	10	biv.	1	biv.
<i>Metapodius terminalis</i>	20	univ.	2	univ.	10	biv.	1	biv.
<i>Chariesterus antennator</i>					12	biv.	1	biv.
<i>Alydus pilosulus</i>	12	univ.	2	univ.	6	biv.	1	biv.
<i>A. eurinus</i>	11	univ.	2	univ.	6	{ 5 biv. 1 univ. }	1	biv.
<i>Corizus lateralis</i>					6	biv.	2 or 3	{ 1 biv. 1 or 2 univ.
<i>Harmostes reflexulus</i>	11	univ.	2	univ.	6	{ 5 biv. 1 univ. }	1	biv.
<i>Protenor belfragei</i>	11	{ 10 univ. 1 biv. }	2	univ.	5	biv.	2	biv.
<i>Cymus angustatus</i>					12	biv. (all?)	1	biv.
<i>Ichnodemus falicus</i>	14	univ.	2	univ.	7	biv.	2 or 3	?
<i>Pellopelta abbreviata</i>	14	univ.	2	univ.	7	biv.	1	biv.
<i>Cedancala dorsalis</i>	11	univ.	2	univ.	6	{ 5 biv. 1 univ. }	1	biv.
<i>Oncopeltus fasciatus</i>	14	univ.	2	biv.	7	biv.	2	biv.
<i>Leptopterna dolabrata</i>					16	biv.	1	biv.
<i>Calocoris rapidus</i>	28?	univ.	5?	univ.	14	biv.	3	{ 2 biv. 1 univ.
<i>Pœcilocapsus lineatus</i>					16?	biv.	2	{ 1 biv. 1 univ.
<i>P. goniphorus</i>					17? 14?	biv.	4	biv.
<i>Phymata</i> sp.....	28	univ.	2	univ.	14	biv.	1	biv.
<i>Coriscus ferus</i>					9	biv.	2	{ 1 biv. 2 univ.
<i>Acholla multispinosa</i>	24	univ.	8	univ.	12	biv.	4	biv.
<i>Sinea diadema</i>					14	biv.	3	biv.

SPECIES.	SPERMATOGONIA.				SPERMATOCYTES.			
	Chromosomes.		Chromatin nucleoli.		Chromosomes.		Chromatin nucleoli.	
	No.	Valence.	No.	Valence.	No.	Valence.	No.	Valence.
<i>Prionidus cristatus</i> ?	21?	?	5?	univ.				
<i>Milyas cinctus</i>							3	biv.
<i>Limnobates lineata</i>							1	biv.
<i>Hygotrechus</i> sp.	18	univ.	2	univ.	9	biv.	2	univ.
<i>Limnotrechus marginatus</i>					10?	biv.	1?	biv.?
<i>Pelocoris femorata</i>	20?							
<i>Zaitha</i> sp.	22	univ.	2	univ.	11	biv.	2	univ.

The following general deductions may be drawn from the consideration of these facts. Whenever there is an even number of univalent chromosomes in the spermatogonia, they unite in the synapsis to produce exactly half this number of bivalent chromosomes. When there is an uneven number in the spermatogonia (*Alydus eurinus*, *Harmostes*, *Protenor*, *Edancala*) all but one of the chromosomes unite in the synapsis to form bivalent chromosomes, while the odd one remains single.

(a) *Number and Genetic Relationship.*

At the outset of the present study I was particularly interested to determine whether the numbers of chromosomes might afford clues to the relationship of the group of the *Hemiptera heteroptera*; that is, to learn, if possible, whether the number would afford a taxonomic criterion. Most of the families of the *Hemiptera* are very rich in species, however, and I have been able to procure only a few species for study, so that the present beginning must be continued on many more species before any conclusion can be reached.

In the *Pentatomidæ*, counting the chromosomes in the spermatogonia, and not including the chromatin nucleoli, we find the number varies between twelve and sixteen, fourteen being most usual; in the *Coreidæ* we find twenty in *Anasa* and *Metapodius*, in *Alydus* eleven and twelve, in *Harmostes* and *Protenor* eleven. In the *Lygaeidæ*, fourteen in *Ichnodemus*, *Peliopelta* and *Oncopeltus*, eleven in *Edancala*, and probably twenty-four in *Cymus*. These were the three families of which the most species were examined. From these numbers it will be seen that there is considerable variation in number for the different species of one and the same family. Accordingly we must conclude either (1) that the number of chromosomes is easily modified and changed, so that it has little

taxonomic value; or (2), that the families of the *Hemiptera heteroptera*, as they are at present defined, are artificial and not natural groups. I would incline to the latter view, since all our facts would show that chromosomes are very conservative structures, and that the germinal cycle is conservative; probably the soma may be modified by the action of the environment to considerable extent, before any such action would produce a change in the number of chromosomes. If this standpoint is correct, then the number of the chromosomes would be a very important consideration in deciding the relationship of species; thus the *Coreidæ* would have to be subdivided into a sub-group with twenty to twenty-four chromosomes (*Anasa*, *Metapodius*, *Chariesterus*), and into one with eleven or twelve chromosomes (*Alydus*, *Corizus*, *Harmostes*, *Protenor*). But it would be a *reductio ad absurdum* to say that all forms with twelve chromosomes must be related, or all forms with twenty; the relative boundaries of a family must still be determined from the standpoint of broad comparative anatomy, and then within a group so defined the chromosomal number might be used as a basis for further subdivision.

(b) *Factors Determining the Number.*

A problem of great importance, and one that would seem to lie close to the root of all nuclear phenomena, is that concerning the factors which determine the number of chromosomes. The germ cells of each species have a fixed number of chromosomes, but different species show a very different number, from *Ascaris megalocephala univalens* with 2 up to *Artemia* with about 180. What is it that determines this numerical difference? A consideration of the various thinkable factors allows us to limit the problem somewhat, by excluding certain ones which are not real factors. Here we may consider in what relation to chromosomal number stand centrosomes and achromatic spindle elements, number of nucleoli, mass of nucleus and cell body, form of cell, volume and form of chromosomes.

The size, number and specific peculiarities of the centrosomes seem to have no connection with the number of the chromosomes. The definite number of chromosomes appears in the prophases of mitosis while the nuclear membrane is still intact, and when the centrosomes are only commencing to exert an influence upon the other cell constituents. Even the longitudinal splitting of the chromosomes would appear to be an automatic movement on their part. The centrosomes may well be centres of movements which produce the separation of the daughter chromosomes, but there appears to be no correlation between the centrosomes and the chromosomal number. And this seems also to be the case with regard to the spindle fibres. Central spindle fibres and polar radiations may vary in their phenomena in different generations of the same species, but the number of the chromosomes remains constant in all generations of the germ cells, for the apparent

halving of the number just before the maturation mitoses is not a real halving of the normal number, but only a grouping into pairs. And the mantle fibres, those which connect the centrosomes with the chromosomes, seem in fact to have their number determined to some extent by the number of the chromosomes, and not to determine that number, for the definite number of chromosomes appear in mitosis before the mantle fibres arise. The number of the connective fibres, those which connect corresponding daughter chromosomes in the anaphase, is certainly determined by the number of the chromosomes, for these fibres are stretched-out portions of the linin matrices of the chromosomes. Thus the centrosomes and the achromatic spindle structures may play a part in the distribution of the chromosomes, but apparently have no part in the determination of their number.

As for the true nucleoli, their number, volume and position seem to be in no way regulative of the chromosomal number. The nucleolar number in one species is generally variable, and correlatively also the volume and position, while the chromosomal number is constant; in the paternal germ cells the number of nucleoli is frequently different (and generally smaller) than that in the maternal cells of a species, but in both kind of cells the number of chromosomes is the same.

The mass of the nucleus or of the cell body, or the relative mass of the two, might seem *à priori* to stand in connection with the chromosomal number, yet an examination of the facts shows this is probably not the case. For instance, in one species the huge ovocytes and the much smaller spermatocytes have the same number of chromosomes, and a small ovogonium has the same number of chromosomes as a large ovocyte. And in the case of the ovocyte the volume of the nucleus is relatively small, in the spermatocyte relatively large in proportion to the mass of the cell body, yet the number of the chromosomes is the same. The mass of the chromatin substance may be more or less proportionate to the volume of the nucleus, but the number of the chromosomes appears not to be; the large number of chromosomes in *Artemia* (as determined by Brauer) is not correlated with a large nucleus; and as the figures of the present paper show, cells of approximately the same size from different species may show very different chromosomal numbers. The form of the cell is regulated to great extent by external influences, and variations in the form produce no modification of the chromosomal number.

The volume of the chromosomes in mitosis is dependent upon their number, since the volume of the chromatin stands in more or less direct ratio to the volume of the nucleus. The form of the chromosomes is more or less dependent upon their number, inasmuch as long ribbon-shaped chromosomes occur only where there are a small number, and rounded ones where there are a larger number present. Yet in all the *Hemiptera*, with their considerable differences in chromosomal number, the form of the chromosomes

remains quite constant, each univalent chromosome being generally slightly elongate. Thus the form is not wholly dependent upon the number, but particular groups of *Metazoa* appear characterized by particular forms of chromosomes, as *e. g.* the *Mollusca* with their rod-shaped chromosomes. Then the form of bivalent chromosomes is dependent upon the mode of junction of the component univalent elements. In no sense, however, can the form of the chromosomes be said to determine their number.

So far our considerations lead to only negative results; centrosomes and achromatic spindle structures, nucleoli, absolute and relative mass of nucleus and cytoplasm, cell form and chromosomal form seem not to be factors determining the number of chromosomes. As I attempted to show in a preceding paper on *Peripatus* (1901), the chromosomes must be regarded as individuals of a lower grade than what I termed the "nuclear element," namely, the linin spirem with the chromosomes arranged upon it. The problem is really, then, why does this nuclear element show in one species a certain number of chromatin segregations, in another species a different number? The more recent chemico-physiological studies would tend to show that the chromosomes are centres of metabolic activity, and accordingly the problem of the factors governing the chromosomal number may be closely connected with the phenomena of metabolism; the number of the chromosomes may be dependent upon the nature of the metabolism, as upon either the chemical nature of the chromosomes themselves or upon that of the cell nutriment. The latter might be experimentally tested by changing the food of a species, and observing whether differences in the number of the chromosomes might thereby be obtained. But to conclude that the number of the chromosomes is dependent upon the nature of the metabolism does not solve the problem but only states it more precisely.

Another question which arises in this connection is whether a small or a large number of chromosomes is to be regarded as the primitive condition. *A priori* it would appear probable that at an early phyletic period the number of chromosomes was not fixed for the species but variable, and that by a process of natural selection the number gradually became fixed. But as a species gradually changes into another form the number of chromosomes may also be changed, as will be shown in the next section, so that we may speak of an evolution of the number of chromosomes. On the principle of the law of greater condensation of organs in progressing evolution, it might be that a large number of chromosomes represents a more primitive condition than a smaller number. Within such a group as the *Hemiptera heteroptera*, for instance, forms like the *Belostomatidæ*, *Reduviidæ*, *Capsidæ* and *Phymatidæ* would be primitive in possessing a larger number of chromosomes, while the *Pentatomidæ*, *Scutellariidæ* and *Lygæidæ* in possessing a smaller number should be regarded as more specialized—more highly developed. From such a standpoint as this, the chromosomal number would be of taxonomic

value—it would be a signboard of degree of specialization within the group. From such a point of view it might even be possible to construct a cellular classification which would have great value in that it would employ truly conservative structures. The centrosomes and central spindles have been considered phyletically in this way by Bütschli, Lauterborn, Heidenhain, Calkins and others, but so far the chromosomes have not been considered from such a standpoint, although they in many respects appear more conservative than centrosomes and achromatic spindle structures.

Accordingly, though the present study has not given a solution to the problem of the factors governing the number of chromosomes, except in showing that it must be sought in the phenomena of metabolism, yet it would show that chromosomal number may be employed as a criterion of relationship if it be used with caution and with due consideration of a broad comparative treatment of other structures. And the reason is because the chromosomes seem to be highly conservative, their number constant for the species, and because in a certain sense they represent the most important vital structures. We should not conclude that all forms with *e. g.* ten chromosomes should be ranked as closely related; all with *e. g.* twenty-four as composing another natural group. But within a certain group which has been defined on a broadly comparative basis—such a group as the *Hemiptera heteroptera*—for instance, the chromosomal number would perhaps be a clue to the relative degree of specialization of the species.

(c) *Significance of the uneven normal number.*

One of the most unexpected results of this investigation was the discovery that in some species there is an uneven number of chromosomes in the spermatogonia, *i. e.*, an uneven normal number, whereas heretofore all observation and assumption has been that the normal number is always an even one. Of the *Hemiptera* studied, four species show an uneven number of chromosomes in the spermatogonia, namely, *Alydus eurinus*, *Harmostes reflexulus*, *Protenor belfragei* and *Eduncula dorsalis*; in all of these the number is eleven, and in the synapsis stage one chromosome remains univalent while the ten remaining combine to form five bivalent chromosomes. What is the significance and origin of this uneven number?

Now, as far as our facts go, it seems that the number of the chromosomes is constant for the species, and that the paternal and maternal germ cells of a species have the same number; this appears to be one of the points in the correspondence of the ovogenesis and spermatogenesis first determined by Henking (1890) and O. Hertwig (1890). Whenever there is this correspondence in number and valence, then in fertilization, when the paternal chromosomes are added to the maternal, an even number of chromosomes should result, and if the chromosomes maintain their individuality through the succeed-

ing generations, there should be an even number in the spermatogonia and ovogonia. The uneven number discovered in the four species mentioned may have arisen in one of two ways: through bastardization, or through a mitotic abnormality, each of which possibilities may now be considered.

In the case of bastardization of a germ cell with one chromosomal number by a germ cell from another species with a different number, the uneven number eleven might be secured if a paternal germ cell of a species *A*, with the normal chromosomal number twelve, fertilizes a maternal germ cell of a species *B* with the normal number ten. In species *A* the reduction in number of the chromosomes would give six univalent chromosomes in the spermatid, and in species *B* five univalent chromosomes in the matured ovum; conjugation of the two cells would then result in $6 + 5 = 11$ univalent chromosomes. In this way an uneven chromosomal number may have arisen by the conjugation of the germ cells of species with different numbers of chromosomes. But the objection to this view lies in the fact that hybridization of distinct species is generally infertile, and species which would have different chromosomal numbers would probably be quite distinct.

More probably, then, the uneven number may have originated through abnormalities of mitosis, and there would be many possibilities for such an occurrence. (1) It may have arisen in a spermatogonic mitosis, in a species where the ancestral normal number is twelve, by the chromatin of the spirem segregating abnormally into only eleven chromosomes, so that one of these chromosomes would be virtually bivalent. This would seem to have been the origin of the large odd chromosome *x* of *Protenor belfragei*, which appears bipartite in the spermatogonia and also in the spermatocytes, though in the latter it does not conjugate with any other chromosome. Such a case would be a deficiency in the segregation of the chromatin in the prophases of mitosis. (2) Or the uneven chromosomal number may have arisen by an unequal distribution of the chromosomes in the anaphases of mitosis, so that the daughter cells would not receive equal numbers.

Now, whether the uneven chromosomal number had originated through bastardization, or, what would be more probable, through abnormality in mitosis, it is interesting to determine how this number can perpetuate itself through different generations of the species, for my observations show that in the species where it is found it occurs in all individuals. The following table gives in condensed form the mode of reduction of the chromosomal number and valence in the four species in question, the chromatin nucleoli being omitted for the sake of simplicity:

SPECIES.	SPERMATOGONIUM.	FIRST SPERMATOCYTE.	SECOND SPERMATOCYTE.	SPERMATID.
<i>Alydus eurinus</i> .	11 univalent.	5 bivalent. 1 univalent.	5 univalent. 1 semivalent.	5 or 6 semivalent.
<i>Harmostes reflexulus</i> .	11 univalent.	5 bivalent. 1 univalent.	5 univalent. 1 semivalent.	5 or 6 semivalent.
<i>Protenor belfragei</i> .	10 univalent. 1 bivalent.	5 bivalent. 1 bivalent.	5 univalent. 1 univalent.	5 semivalent. 1 or 0 univalent.
<i>Ædancala dorsalis</i> .	11 univalent.	5 bivalent. 1 univalent.	5 univalent. 1 semivalent.	5 semivalent. 1 (or 0 ?) semivalent.

It may appear strange that the chromosomes of the spermatids are classed as semivalent since they are generally considered univalent; as I have explained in an earlier portion of this paper, however, they must be regarded as semivalent on account of the absence of a rest stage between the maturation mitoses, though they are virtually univalent on account of their increase in mass during the growth period. *Protenor belfragei* differs from the three other species in showing a bivalent chromosome in the spermatogonium, which chromosome is consequently bivalent in the first spermatocyte even though it unites with no other during the synapsis stage. All four species have in common the phenomenon that the odd chromosome does not conjugate with any other during the synapsis stage, but remains separate. In *Alydus eurinus*, *Harmostes reflexulus*, and *Protenor belfragei* this odd chromosome does not divide in the second maturation mitosis, but passes undivided into one of the two spermatids. In *Ædancala dorsalis* I was unable to determine its behavior in this mitosis, though I have no reason to suppose that here it behaves differently from the other species. This unequal distribution of the odd chromosome in the second maturation mitosis is evidently in some way dependent upon its not having united with a fellow-chromosome during the preceding synapsis stage. What concerns us particularly at present is the fact that in these species with an uneven normal number of chromosomes, unlike those with an even number, one chromosome (the odd one) is not divided in the second maturation mitosis, but passes undivided into one of the daughter cells (spermatids); half of the spermatids then have six chromosomes and half have only five.

Bearing this point in mind, let us see how the uneven chromosomal number may be perpetuated from individual to individual. This may be occasioned by one of two possibilities. (1) The paternal germ cells having eleven chromosomes in the spermatogonia and either five or six in the spermatids, there is the probability that the maternal germ cells (ova) may have a corresponding number of chromosomes. If a spermatozoon with

five (or six) chromosomes conjugates with an ovum with five (or six), so that each of the conjoints has the same number, an even number would result in the fertilized ovum. But if a spermatozoon with five (or six) chromosomes unite with an ovum with six (or five), the conjoints having then different numbers of chromosomes, the fertilized ovum would have the uneven number eleven; the uneven number would then be perpetuated from individual to individual, so long as the conjugating cells have different numbers of chromosomes, and so long as the odd chromosome does not divide in one of the maturation mitoses. (2) Or germ cells from individuals with an uneven normal number of chromosomes, by conjugating with germ cells from individuals with an even number, would occasion an uneven number in the fertilized ovum. Either of these possibilities would suffice to explain the transference of the uneven number from individual to individual, though the first possibility would appear the more probable.

So far we have considered the origin of the uneven chromosomal number and the mode by which it is perpetuated from individual to individual. We have now to discuss its significance. Most of the *Hemiptera* examined by me show an even normal number of chromosomes; only four showed an uneven number, and in no other *Metazoa* has an uneven number, to my knowledge, been found. The uneven number would accordingly appear to be unusual. It seems to me probable that the uneven number represents a transition stage between a higher number and a lower, or the converse, and it is unusual because the transition stage is probably shorter than the earlier and the later stages. The number of the chromosomes varies quite considerably in the different species of the *Hemiptera heteroptera*, but we cannot suppose that the number was constant for each species from the beginning any more than we can consider that the species have always remained unchanged; there must have been an evolution of the chromosomal number, as there has been of the species. It is quite possible that an even number of chromosomes, as *e. g.* twelve, may have changed into an even number (ten) without first passing through the stage of the uneven number (eleven). This might take place by the number ten appearing simultaneously in both paternal and maternal germ cells through some abnormality or deficiency in mitosis. But it is far more probable that such a mitotic abnormality would not occur coincidentally in both kinds of cells—more probable, *e. g.*, that a paternal germ cell, acquiring an abnormal number of chromosomes by some fault in the process of mitosis, would conjugate with a maternal germ cell with the normal number; the result of such a union would be of course an uneven number. On this argument, when the chromosomal number changes, the period of change would be characterized by an uneven number of chromosomes. Ultimately an even number of next lower or next higher order would be reached, and that number must persist longer than the uneven number in view of the fact that uneven numbers are comparative rarities. If both paternal and maternal

germ cells gradually acquired the same uneven number of chromosomes, then by conjugation of such cells, similar numbers of chromosomes being added together, a new even number would result. But there is still another possibility by which the uneven number could pass into an even one. The odd chromosome, at least in the cases here described, does not divide in the second maturation division, and so behaves abnormally. Now such an abnormally behaving chromosome might in time become differentiated from the other chromosomes, and I venture the view that such odd chromosomes are on the way to become chromatin nucleoli. The main fact on which this conclusion is based is that in *Protenor belfragei* it is the odd, the eleventh chromosome—the “chromosome x ”—which in the spermatocytic growth period evinces the phenomena of a chromatin nucleolus. Then another correspondence is that the chromatin nucleoli in most *Hemiptera* act like the odd true chromosome in usually not dividing in the second maturation division. Here we have an explanation for the origin of those peculiarly modified chromosomes, the chromatin nucleoli, thoroughly in accord with the facts I have described for them: the chromatin nucleoli are modified chromosomes, in point of origin the odd chromosomes which appear in the period of transition from a higher (or a lower) to a lower (or higher) even normal chromosomal number. And there are generally two chromatin nucleoli in the spermatogonia, because the odd chromosome in those cases where there is an uneven normal number had probably been formed in most cases, as it certainly appears to have originated in *Protenor belfragei*, as a union of two univalent chromosomes which had failed to separate from one another in the spirem stage of the spermatogonic mitosis. This also explains why the two chromatin nucleoli are generally placed close together in the monaster stage of the spermatogonium, they having been originally contiguous in the spirem thread.

Such an explanation of the origin of the chromatin nucleoli from the odd chromosomes seems to be in accord with all the facts, and so far may be considered a true explanation. The chromatin nucleoli are modified chromosomes, and it is the odd chromosomes which become thus modified. Conversely, we should expect that chromatin nucleoli would be formed whenever the chromosomal number in changing from a higher to a lower one, or the converse, passes through a transition period of an uneven number. Now, as has been shown in the descriptive part of this paper and tabulated on page 207, all the *Hemiptera* examined have two chromatin nucleoli, but some have a larger number. Wherever there is a larger number we find generally that they are of different volumes, and the question arises: why this difference in volume? The explanation might be that the largest ones are those most recently formed; the smallest those which had been evolved at earlier periods, and which are smaller because they are perhaps diminishing through a gradual degeneration. If the chromatin nucleoli when once formed should always preserve their

original size, there should be no gradations in volume—no degeneration on their part—so that in a given species we could determine by their number how many times the chromosomal number had changed. But when new chromatin nucleoli are formed, the older ones would seem to degenerate in the order of their formation. This assumption would explain the occurrence of very minute chromatin nucleoli found in cells of certain *Hemiptera* along with much larger ones; the minute ones would represent chromatin nucleoli formed at earlier periods, now on the way to total degeneration and disappearance. We might explain the general occurrence of one pair in the spermatogonia, or of one bivalent one in the spermatocytes, on the conclusion already reached in an earlier part of this paper, that the chromatin nucleoli are metamorphosed for a special function different from that of the other chromosomes and so necessary for the nuclear activity; and the reason for their degeneration when new ones are formed, in that a single pair would generally appear to be sufficient for this function, so that not more than one pair would remain in functional activity at one time.

Thus we find that the unexpected discovery of an uneven chromosomal number in the spermatogonia opens the way to an explanation of certain phenomena, and suggests others not anticipated. It suggests that there is a gradual evolution in the numbers of chromosomes; that they have not been fixed from the start, but that with the evolution of the species the chromosomal number changes and at each change probably passes through a period with an uneven number. In the *Hemiptera* this would seem to be, in the forms examined, a change from higher to lower numbers, and in such a change the odd chromosome becomes metamorphosed—becomes a metamorphosed chromatin nucleolus. If attention be given to these points in other groups of animals, there can be little doubt that there, too, will be found occasional examples of uneven normal chromosomal numbers, and probably also in some of these cases the production of structures comparable to the chromatin nucleoli of the Insects. There is great need, first of all, however, to determine for the *Hemiptera* whether in such cases there is a close correspondence between the spermatogonesis and ovogenesis—that correspondence I have assumed, since I have not studied the ovogenesis.

4. *Considerations on the Cycle of the Germ Cells.*

Here shall be considered in succession some points of broader interest which have arisen in the course of my studies on spermatogenesis.

(a) *The sequence of the stages of the cycle.*

In the germ cells of the *Metazoa* there may be seen regular cycles of generations following upon one another. In each cycle may be noted a stage of conjugation of ma-

ternal and paternal cells or stage of fertilization; upon this follow a number of ovogonic or spermatogonic generations, the exact number of which has not yet been determined for any metazoon; the last generation of the ovogonia or spermatogonia give rise to ovocytes or spermatocytes of the first order, and these are characterized by the synapsis stage and growth period when the reduction in the number of chromosomes is effected, the synapsis stage being evidently coincident in all forms with the commencement of the growth period; and finally occur two maturation divisions which result in the formation of ootids or spermatids. The spermatids undergo an elaborate metamorphosis to become spermatozoa; but since such a metamorphosis is not found in the ootids, we may disregard this stage, which evidently is far less conservative than the others; from the comparative standpoint the metamorphosis of the spermatozoon is of much less morphological significance than the preceding stages of spermatogenesis, and would appear from the recent investigations to be far more variable.

Thus each germinal cycle shows the following well-marked stages: conjugation or fertilization, a stage of a number of ovogonic or spermatogonic generations, the synapsis stage coincident with the growth period, and the stage of the two maturation divisions. Each such cycle is succeeded by a similar one, and so on indefinitely for an indefinite number of cycles. Now it is unthinkable that a cycle should be without a beginning; it must have been gradually evolved, and some particular stage in it must have been the starting point. What was this first stage? An answer is necessary before we can enter into the discussion of the meaning of the synapsis stage.

It appears to me most probable that the stage of conjugation of the germ cells must be considered the starting point. For from the studies of R. Hertwig and Maupas on Infusoria, it appears probable that conjugation or fertilization is essentially a process of rejuvenation: cells may divide and reproduce for a number of generations asexually, but there comes a period when the cellular vitality diminishes, so that no further reproduction is possible except after rejuvenation afforded by conjugation with another cell. When thus rejuvenated by admixture of substances from the other conjoint, the cell starts upon a new period of generation—the period of conjugation thus being the commencement of a cycle. As we shall see, the synapsis stage is really a delayed part of the process of conjugation, and the growth period is induced by the synapsis of the chromosomes. Having determined the starting point of the germinal cycle, we may now consider the meaning of the synapsis stage.

(b) *The phylogeny of chromosomes and the significance of the synapsis stage.*

In the considerations that follow I assume that through the germinal cycle the chromosomes preserve their individuality from generation to generation—*i. e.*, that a particular

chromosome of one generation is represented in a particular one of a preceding, so that chromosomes are not produced *de novo* in each generation. The evidence for this assumption, as regards the *Hemiptera*, has been already stated above (cf. the heading: "The process of spermatogenesis in the Hemiptera"); other evidence was shown in my study on *Peripatus* (1901), and there also the observations of other workers was considered in some detail so it is not necessary at this point to enter into these particulars. Without this assumption, which is an actuality, as I have shown in some cases, it would be very difficult to determine the meaning of the stages of the germinal cycle; while on this assumption much becomes clear, and the phenomena of the synapsis stage alone are strongly corroborative of this assumption.

Now in the cycle of the germ cells there is a chromosomal peculiarity which has been described by other investigators, but its significance has not been understood; I referred to it in my study of *Peripatus* (1901). In the anaphases of the male and female pronuclei, as in the anaphases of the early cleavage cells, it is characteristic that each chromosome becomes vesicular so that at this stage each daughter nucleus appears composed of as many such vesicles as there are chromosomes. Each vesicle has its own limiting wall, and not infrequently the different vesicles may be only loosely connected together; ultimately, however, when the complete rest stage is attained, the boundaries between the vesicles disappear so that the nucleus appears a whole without separated parts.*

Rückert (1895) supposes the chromosomal vesicles to represent a shortened anaphase, occasioned by the rapid sequence of the mitoses in the blastomeres; that this is hardly a correct explanation is seen from the following considerations. From the list of cases just mentioned in the footnote it will be seen that anaphases with vesicular chromosomes are found in the pronuclei and in the earlier cleavage cells—*i. e.*, in nuclei at the beginning of the germinal cycle. I have never seen such vesicular stages in the last generations of ovogonia and spermatogonia, nor to my knowledge has any one else; but in these later

* This vesicular stage of the chromosomes in the anaphases of mitosis has been described by the following workers, though this is probably not a complete list: Remak (1855, cited by Henneguy, 1896, blastomeres of *Batrachia*); Oellacher (1872, egg of Trout); Trinchese (1875, cited by Henneguy, 1896, pole cells of *Aeolididae*); O. Hertwig (1876, *id. citat.*, blastomeres of *Bufo*); Fol (1879, *id. citat.*, *Toxopneustes* egg); Henneguy (1882, 1891, egg of Trout); Bellonci (1884, cited by Henneguy, 1896, blastomeres of *Axolotl*); Schwarz (1888, *id. citat.*, blastomeres of Trout); Van der Stricht (*id. citat.*, larval epidermis of *Salamandra* and *Triton*, megacaryocytes, leucoblasts and erythroblasts of embryonic liver of Mammals); Mead (1895, 1898, *Chatopterus*, female pronucleus and blastomeres up to 16-cell stage); Foot (1894, 1897, female pronucleus of *Allolobophora*); Sobotta (1897, pronuclei and first cleavage of *Amphioxus*); Kostanecki and Wierzejski (1896, male and female pronuclei of *Physa*); v. Klineowström (1897, male and female pronuclei of *Prosthoceraeus*); Rückert (1895, blastomeres of *Cyclops*); O. Schultze (1887, blastomeres of *Axolotl*); Koelliker (1889, blastomeres of *Siredon*); Van Beneden and Neyt (1887, blastomeres of *Ascaris*); Böhm (1888, male and female pronuclei and first cleavage of *Petromyzon*); Wheeler (1897, female pronucleus of *Myzostoma*, occasionally showing widely separated chromosomal vesicles); Coe (1898, female pronucleus and first cleavage of *Cerebratulus*); Boveri (1888, blastomeres of *Ascaris*).

germinal stages, as well as in apparently all adult tissue cells (compare Flemming, 1882, 1890; Zimmermann, 1890; Rabl, 1885; Torok, 1888), there is generally no such vesicular stage during the anaphase—it is then characteristic of embryonal cells, of those at the commencement of the generative cycle. An explanation of a possible reason for the chromosomal vesicles maintaining their independence was given in my paper on *Peripatus* (1901), where I referred it to the breaking of the linin spirem effected by the reduction mitosis, and maintained that no continuous chromatin spirem could be formed—*i. e.*, no close juxtaposition of the chromosomes be effected until the linin spirem had become restored.

Probably the chromosomal individuality is maintained through all the generations of the cycle, but the chromosomes seem to show their independence most markedly in the early stages, where it is strikingly evinced by their vesicular phenomena. Each vesicle appears to be potentially a little nucleus, with its ova wall, its chromatic reticulum and caryolymph, and sometimes with its own nucleoli. This is very suggestive of the possibility that each chromosome may represent, from the phyletic point of view, a nucleus; and a metazoan nucleus would then be a symbiotic union of as many nuclei as there are chromosomes. Such a conclusion might explain why the chromosomes pass through vesicular phases resembling nuclei in the earlier periods of the cycle.

So far we have seen that in the earlier portion of the germinal cycle the chromosomes remain more disconnected from one another than at later periods; in the later periods, those *e. g.* of the last generations of the spermatogonia and ovogonia, they no longer show vesicular, nuclear-like appearances in the anaphases, and appear to be more dependent upon one another—less independent. Now another line of facts may be considered in this regard. Van Beneden (1883, 1887) first showed that in the fertilized egg of *Ascaris* the paternal and maternal chromosomes remain separated from one another, so that in the prophases of the first cleavage mitosis a paternal and a maternal chromatin spirem is formed; thus Van Beneden concluded a maintenance of the individuality of the pro-nuclei. Then Rückert (1895) found in the cleavage cells of *Cyclops* that the paternal and maternal chromosomes form two separate groups throughout the mitosis, and that even in the rest stage there is a double nucleus, half paternal and half maternal; in the prophases there is a paternal chromatin spirem distinct from the maternal one. Up to about the 32-cell stage Rückert was able to find these double nuclei, but found that in later cleavage stages they gradually decrease in number. But Rückert is probably in error when he concludes that the separation of the paternal and maternal chromosomes is retained even up to the time of the first maturation mitosis (first pole spindle). He bases this conclusion on the discovery that in the equatorial plane of the spindle at this stage the chromosomes are arranged “*ausnahmslos*” into two groups. Now here the chromo-

somes are bivalent and eleven in number, so that each group cannot have the same number. Thus out of the cases examined by him, in twelve cases the chromosomes were in groups of relatively equal number (relation of six to five); in two cases, one group had four, the other group seven chromosomes; in three cases, they were arranged in groups of three and eight, respectively; and in one case, in groups of two and nine, respectively. Thus, though there may be at the period of the first maturation mitosis an arrangement of the chromosomes into two groups, yet the variable discrepancy in the number of the chromosomes composing the two groups shows that it is impossible that one group has only paternal chromosomes and the others only maternal, for the reason that at the start (in the fertilized egg) paternal and maternal chromosomes are equal in number. Accordingly, Rückert has shown for *Cyclops* that the maternal and paternal chromosomes form separate groups up to about the 32-cell stage, when the separateness of these groups gradually disappears; and his own descriptions and figures would show that at the time of the first maturation mitosis there is no longer a paternal group of chromosomes separate from a maternal group. There could also be mentioned the observations of other authors to the effect that the paternal and maternal chromosomes compose separate groups in the early cleavage cells, as especially the observations of my colleague, Prof. Conklin, on the eggs of *Crepidula*.

Accordingly, we have seen that in the earlier period of the germinal cycle, at the time of fertilization and the immediately following generations, paternal and maternal chromosomes remain separated from one another, and also that the individual chromosomes show a remarkable degree of independence as evinced by their vesicular phenomena in the anaphases. In the later stages of the germinal cycle, on the contrary, paternal and maternal chromosomes appear no longer to be arranged in separate groups, and the chromosomes themselves are no longer vesicular in the anaphases.

Now for the bearing of all this on the question of the significance of the synapsis stage. At the commencement of the germinal cycle, the stage of conjugation of the germ cells, the chromosomes are more distinct from one another than at any later stage; this distinctness gradually disappears as the cycle progresses, and at the time of the synapsis stage the chromosomes actually join together to form half the normal number of (bivalent) chromosomes. What chromosomes are these which unite to form pairs? Does a paternal chromosome unite with a paternal and a maternal with a maternal, or does a paternal chromosome unite with a maternal one? The following considerations show that the latter view is probably the true one.

First of all, in *Ascaris megalocephala univalens* there is the normal number of two chromosomes; as Brauer (1893 b) has demonstrated, one of these is paternal, the other maternal in origin; since these two unite to form one bivalent one in the synapsis stage,

this would be a union of a paternal with a maternal chromosome. Also in the *Hemiptera*, whenever there are in the spermatogonia two chromosomes which are distinguishable from the others by their greater size, as in several species described in this paper—*e. g.*, *Protenor belfragei*—these two especially large ones always unite together in the synapsis to form one bivalent one much larger than the other bivalent ones, and one of the large ones does not unite with a small one; now it can be shown that one of these large chromosomes is paternal and the other is maternal. For calling the two large chromosomes of the spermatogonia *a* and *b*, respectively, they unite in the synapsis to form the bivalent chromosome *ab*; the first maturation mitosis (here a reduction division) gives *a* to one daughter cell (second spermatocyte) and *b* to the other; the second maturation division of the one of these daughter cells gives to each spermatid $\frac{1}{2}a$, the corresponding division of the other daughter cell $\frac{1}{2}b$ to each spermatid. What we find in each of these spermatids is only *one* especially large chromosome, and not *two*. Accordingly, in order for there to be *two* in the spermatogonia, the egg cell must furnish *one*, and then that *one*, together with the *one* furnished by the spermatozoon in fertilization, would make up the *two*. Then of the two particularly large chromosomes of the spermatogonium, one would be paternal and one maternal, and since these two unite in the synapsis stage, this would be a union of a paternal chromosome with a maternal chromosome. A case where two particularly large chromosomes are distinguishable in the spermatogonia was selected for discussion, because these two, on account of their peculiarity in size, can be recognized through the maturation divisions; but if the conclusion be true that one of the large chromosomes is paternal and one maternal, and that these two join together in the synapsis, then it would be very probable that each of the other bivalent chromosomes of the spermatocytes represents a univalent paternal chromosome united with a univalent maternal one. This case, as the one of *Ascaris megalocephala univalens*, may be considered very positive cases in favor of the union of paternal with maternal chromosomes in the synapsis stage. There is still another point of view which makes this conclusion very probable. As we have seen, whenever there is an even number of chromosomes in the spermatogonia, exactly half that number of bivalent chromosomes are formed in the synapsis; thus in *Euchistus variolarius* there are fourteen univalent chromosomes in the spermatogonia, and seven bivalent ones in the first spermatocytes. Now seven of these chromosomes are paternal and seven maternal, since the spermatids have only seven. The regular formation of seven bivalent chromosomes in the synapsis stage would be only possible if maternal chromosomes united with paternal ones. For if, on the contrary, paternal chromosomes united with paternal and maternal with maternal, then of the seven paternal chromosomes three bivalent ones could be formed, but there would be left an ununited odd one, and similarly of the seven maternal chromosomes there would remain an ununited (univalent) odd one. But since

in the first spermatocytes of *Euchistus* all the chromosomes are united into pairs, so that there are no chromosomes remaining univalent, it follows that in this case it is impossible that only chromosomes of like parentage should unite together.

These considerations render it very probable that in the synapsis stage is effected a union of paternal with maternal chromosomes, so that each bivalent chromosome would consist of one univalent paternal chromosome and one univalent maternal chromosome. This conclusion allows us to consider the synapsis stage in an entirely new light, and gives an important significance to this stage. The synapsis stage then, which is characterized by the union of chromosomes into bivalent pairs, may be considered the stage of the *conjugation of the chromosomes*. When the spermatozoon conjugates with the ovum there is a mixture of cytoplasm with cytoplasm, of karyolymph with karyolymph, possibly also an intermixture of other substances; but there is then no intermixture of chromatin, for the chromosomes then, as we have seen, remain more separated from one another than at any other stage—in fact, the paternal chromosomes seem to show a repulsion for the maternal, inasmuch as they are arranged in two separate groups. But after this beginning stage of the germinal cycle, the repulsion of the paternal for the maternal chromosomes gradually diminishes, is generally no longer recognizable in the last of the spermatogonic and ovogonic divisions, and in the synapsis stage instead of a repulsion we find a positive attraction between the paternal and maternal chromosomes. The reason for the final union of these chromosomes is obvious: it is evidently to produce a rejuvenation of the chromosomes. From this standpoint the conjugation of the chromosomes in the synapsis stage may be considered the final step in the process of conjugation of the germ cells. It is a process that effects the rejuvenation of the chromosomes; such rejuvenation could not be produced unless chromosomes of different parentage joined together, and there would be no apparent reason for chromosomes of like parentage to unite. At the same time the so-called “reduction in the number” of the chromosomes is effected, but this is probably not primal but rather a necessary result of the conjugation of the chromosomes. And here the point may be made that really there takes place no reduction in the number of the chromosomes in the germinal cycle, but “reduction in number” is simply a convenient phrase for expressing that in the synapsis the chromosomes unite to form pairs; no chromosomes have been lost, there is in the strict sense no reduction in number.

So we find that the synapsis stage has a very broad and important significance, of all the stages in the germinal cycle second only to the initial stage of conjugation of the germ cells. In the synapsis stage we see the final process in the conjugation of the germ cells, namely, the conjugation of the chromosomes. Now following immediately upon the synapsis stage comes the growth period of the spermatocytes and oocytes—that period when the germ cells attain volumes greater than at any other period in the germinal cycle.

Very evidently this great increase in volume is effected by that rejuvenescence of the chromosomes secured by their conjugation. For the chromosomes are centres of metabolic activity, by conjugation of paternal with maternal chromosomes in the synapsis stage their metabolic functions are rejuvenated, and this rejuvenation finds its expression in the great changes of the growth period. So this explanation of the synapsis stage would seem to be in accord with all the facts known at present.

It is quite possible that at an earlier period in the phylogeny, the conjugation of the chromosomes may have taken place at the time of the conjugation of the germ cells, and not have been separated from that stage by a number of generations as in the modern *Metazoa*. But the determination of the original time of occurrence of the conjugation of the chromosomes is highly speculative, and so will not be entered upon here.

It is generally stated (*e.g.* Von Rath, 1893; Rückert, 1894) that the bivalent chromosomes of the spermatocytes and oocytes of the first order are produced "by the spirem segmenting into only half the normal number of chromosomes." This is not a correct statement, since in the prophases of the first maturation mitosis there is, as I have shown in my paper on *Peripatus*, no stage of a continuous chromatin spirem. Further, this general statement is not at all explanatory of the formation of bivalent chromosomes, for it does not express any reason why the chromosomes should be joined into pairs.

It is to Moore (1895) that we owe the first clear characterization and estimation of the synapsis stage; he divided the germinal cycle into the "first period" (conjugation of germ cells, spermatogonic and ovogonic divisions), the "synaptic phases" (coincident with the growth period), and the "second period" (maturation divisions). It will be seen that my own classification of the stages is somewhat more detailed than Moore's, though it is not necessarily any better. The important characteristic of the synapsis stage is, of course, the union of chromosomes into bivalent pairs; the exact details of this process, which appear to differ in different groups, are of secondary significance.

(c) *The significance of the maturation divisions.*

The two maturation divisions of the *Metazoa* represent the terminal stages of the germinal cycle.

In the Copepods (Häcker, 1895; Rückert, 1894), the Isopods (*Oniscus*, in a just finished paper by my student, Miss Louise Nichols), in the Insects (Von Rath, 1892; Henking, 1890; Montgomery, Paulmier, 1899; McClung, 1900), and in *Peripatus* (Montgomery, 1901) there are well demonstrated cases that one of the maturation divisions is a reduction division (*pseudoreduction*, Rückert, 1894) in that it accomplishes a separation of entire univalent chromosomes from one another. Such a reduction division, a transverse splitting of the chromosomes, is not known for any other generation of the germinal cycle, nor for any somatic generation.

But in *Ascaris* (Brauer, 1893 b), in *Salamandra* (Meves, 1896), in the Rat (Lenhossek, 1898), in *Selachii* (Moore, 1895), and in *Amphiuma* (McGregor, 1899) the authorities cited agree that both maturation divisions are equational. Now it does not seem *à priori* probable that in some *Metazoa* a reduction division should occur, and in others not. The case of *Ascaris* would seem to show no sign of a reduction division, for Brauer's careful study apparently shows that each bivalent chromosome becomes split longitudinally twice; yet Sabaschnikoff's more recent study (1898) would show that another interpretation of the phenomena is possible (but not proved), namely, that the chromatin microsomes may become rearranged into fours in such a way that one of the maturation divisions may be reductional. In the Salamander, Flemming (1887) showed that the mitosis of the first generation of spermatocytes has remarkable peculiarities, so that he named it a "heterotypic" mitosis. The most remarkable of its characteristics is that the chromosomes are longitudinally split in shape like horseshoes, and that they open up into the forms of rings, the ends of the daughter horseshoes retaining their mutual connection. Such a heterotypic mitosis was corroborated by Meves in his description of the spermatogenesis of *Salamandra*; and it has been shown to be characteristic of the first maturation division in *Selachii*, the Rat, and *Amphiuma* by Moore, Lenhossek and McGregor, respectively.* All these writers show that the heterotypic mitosis results in a longitudinal division of the chromosome, and there can be no reasonable doubt of the correctness of their descriptions. But I think they are mistaken in concluding that because the heterotypic division is a longitudinal division of the chromosomes, that therefore it is an equation division. For the chromosomes of these spermatocytes are bivalent—there are just half as many in the spermatocytes as in the spermatogonia. Since there is no loss of chromosomes in the spermatocytes, there must take place a union of univalent chromosomes into pairs during some part of the growth period—*i. e.*, in the synapsis stage. I venture the view that in the Vertebrates either (1) the bivalent chromosomes are formed by every two univalent chromosomes becoming apposed to one another side to side—*i. e.*, along their whole length, so that the two would compose a double horseshoe—or (2) by the two ends of one univalent chromosome becoming closely connected with the two ends of the other, so that the whole would have the form of a ring. From what has been described for these bivalent chromosomes, we know that the longitudinal split does not divide their ends, but the ends are unsplit. Accordingly, it would appear probable that the essential process in the formation of these bivalent chromosomes is that the two ends of one univalent chromosome become united with the two ends of another, while it would be of secondary importance whether the two chromosomes might be apposed along their whole lengths or not.

* Moore states that the second maturation division is also heterotypic, but his figures do not prove his point, which needs reëxamination.

But from this it would follow that the heterotypic mitosis of the first spermatocytes of the Vertebrates is really a reduction division, and results in the separation of whole univalent chromosomes. Then the longitudinal split of such bivalent chromosomes would be really the space between two univalent chromosomes. Thus, though these chromosomes may appear in the prophases longitudinally split, yet a separation of the daughter chromosomes along the line of this split would not be an equational division. The workers on vertebrate spermatogenesis have indeed shown that the bivalent chromosomes are split longitudinally, but since none of them have succeeded in demonstrating how the bivalent chromosomes are formed in the synapsis stage they could not show the significance of this longitudinal split. For *Peripatus* and the *Hemiptera* I have shown that a bivalent chromosome is produced by one end of one univalent chromosome uniting with one end of another; while in the *Vertebrata*, if my interpretation is correct, a bivalent chromosome would be produced by the union of both ends of one univalent chromosome with both ends of another—the spermatogonic chromosome is U-shaped, the spermatocytic chromosome is ring-shaped since it represents two such U-shaped elements with their ends connected. Also in *Peripatus* and the *Hemiptera* there are occasionally ring-shaped chromosomes similar to the heterotypic chromosomes of Vertebrates, and they are formed by the two ends of one univalent chromosome being joined with the two ends of another, instead of one end being joined simply with one end.

This interpretation explains, and the process has never been satisfactorily explained before, why one of the maturation mitoses in Vertebrates is heterotypic: it is a reduction division separating entire univalent chromosomes, and it differs from all other mitoses of the germinal cycle because it is the only one of them which does separate entire chromosomes. If this view is true, then probably all *Metazoa* would have in common the occurrence of one reduction division, and we should no longer be confronted by the discrepancy between *Metazoa* with and those without a reduction division. The occurrence of a reduction division is actually proved for the *Copepoda*, *Insecta*, *Oniscus* and *Peripatus* (I shall not mention other objects where it has been rendered probable but not thoroughly proven); *à priori* we should expect that one would occur in the Vertebrates also, and in the Vertebrates there does occur a peculiar heterotypic division which, as we have seen, can be satisfactorily explained as a reduction division. Accordingly, the term “heterotypic mitosis” might be applied to any mitosis which results in the separation of whole univalent chromosomes, irrespective whether it divides the bivalent chromosome transversely or longitudinally; the term “heterotypic” is indeed most excellent in that it expresses a mitosis “of a type of a different kind,” one differing from all other mitoses of the germinal cycle. Of very secondary importance, then, would be the form of the chromosomes—not the form but the way in which the chromosomes divide should be

taken as the criterion of the heterotypic mitosis. This signification would be different from that originally defined by Flemming (1887), but it would certainly be a step toward greater clearness to use "heterotypic" division in the place of the promiscuously used "reduction" division.

Now that we have seen that a reduction division occurs in the *Copepoda*, *Insecta*, *Oniscus* and *Peripatus*, and that the heterotypic division of the *Vertebrata* may be interpreted as a reduction division also, we have to try to explain why such a reduction division occurs. In the synapsis stage there is a conjugation of paternal with maternal chromosomes for the purpose of rejuvenation of the chromosomes as metabolic centres, and this rejuvenation is exemplified in the great metabolic activity of the growth period. Now, R. Hertwig and Maupas have shown for the *Infusoria* that the two conjoints remain for only a certain period in apposition, and that when the interchange of nuclei necessary for rejuvenation has been accomplished the conjoints separate. Of course it is not a true analogy to compare conjugating *Infusoria* (*i. e.*, whole cells) with conjugating chromosomes (*i. e.*, portions of cells). But still it is very probable that two chromosomes unite temporarily for the same reason that two *Infusoria* do, that is, for an interchange of substances; and when the chromosomes have accomplished this interchange there would no longer be any necessity for continued apposition, so they tend to separate from one another. It is the reduction division in *Metazoa* which accomplishes the complete separation, though it may commence in the prophases of this division. It is conceivable that the conjugated chromosomes might separate as they had come together, without the intervention of a mitosis. But in the *Metazoa*, so far as we know, they become separated only by the agency of a mitosis, and that is the reduction mitosis. At the beginning of the germinal cycle there is a repulsion of paternal and maternal chromosomes for one another, during the synapsis a strong attraction, and at the end of the germinal cycle a repulsion again, but not a repulsion so strong as to distribute the chromosomes into two groups in the spermatid and ovid. Only by a reduction division can paternal and maternal chromosomes become wholly separated, for only then do the interchromosomal linin fibres (persisting portions of the linin spirem: compare my paper on *Peripatus*) become broken.

The question is complicated because another maturation division occurs, an equational division: in the *Insecta*, *Oniscus*, *Peripatus* and the *Vertebrata* the reduction division precedes the equational, in the *Copepoda* (according to Rückert, 1894) the reverse is the case. It is not difficult to explain why an equation division should occur at this time, for the cell has increased in volume very greatly during the growth period, and great increase in volume (increase beyond the individual mass) would appear to be a main factor in inducing cell division. With this increase in volume of the cell the chromosomes also increase in volume (though by no means in a direct ratio), and each univalent

component of a bivalent chromosome divides into two longitudinally (equationally), this being the usual mode of division of a chromosome—in fact the only known method of reproduction of univalent chromosomes. From this standpoint the growth period would be the inducer of the equational maturation mitosis, and this mitosis would be strictly comparable physiologically to any other equational mitosis of the germinal cycle. But at the time that the cell is preparing for this equational division, paternal and maternal chromosomes, having accomplished the purpose which occasioned their conjugation, show a tendency to repulsion for each other, and so evince the need of becoming disconnected. The cell already started into mitotic activity would offer mechanical possibilities to effect the separation of the maternal from the paternal chromosomes, so that instead of a single mitotic process there are two in rapid succession, sometimes with not a trace of a rest stage in between, one separating entire univalent chromosomes, the other separating the halves of each univalent chromosome. It would be very enticing to enter here into the mechanics of this mitosis, which would be practically a determination of the points of apposition of the mantle fibres on the chromosomes; but such an inquiry is hardly germane to the present discussion. The point to be made is that in the *Metazoa* there follows after the growth period an equational mitosis, because in the growth period the cell has increased beyond the normal size; and that a reduction division occurs about the same time in order to affect a complete separation from one another of the paternal and maternal chromosomes, which, having accomplished the purpose for which they conjugated, show again a repulsion for each other. The growth period is the inducer of the equational division, the mutual repulsion of chromosomes of different parentage the inducer of the reduction division. The chromosomes in the late anaphases, after the maturation divisions, become vesicular and so show a great degree of mutual independence, because the reduction division had severed their linin connections.

In conclusion, it would be very interesting to enter into the question of the parallelism of the germinal cycle in *Metazoa* and *Protozoa*, as has been done by Henking and Moore (1895). However, it would be well first to have ascertained the significance in the cycle of the *Metazoa*, as far as that can be done without reference to the states in the *Protozoa*. The chromosomes are the cell components on which the problem can be best studied.

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EXPLANATION OF THE PLATES.

All figures have been drawn with the camera lucida at the level of the base of the microscope, with the homogeneous immersion objective $\frac{1}{12}$ of Zeiss and ocular 4, tube length 180 mm. In the majority only the chromatin nucleoli, chromosomes and true nucleoli together with the outline of the nucleus or cell body has been drawn; and in the majority of figures representing lateral views of monaster stages, the mantle fibres, connective fibres, and centrosomes are the only structures shown beside the chromatin elements. For *Euchistus variolarius*, however, the various structures are represented in detail, and this is also the case with some of the figures of various other species.

The following abbreviations have been employed (for others not here mentioned the descriptive text must be referred to):

- C. Mb.*, cell membrane.
N., true nucleolus (plasmosome).
N. 2, chromatin nucleolus (modified chromosome).
N. Mb., nuclear membrane.

Plate I.

Euchistus variolarius, Figs. 1-19

Fig. 1. Nucleus of spermatogonium, rest stage.

Figs. 2, 3. Pole views of spermatogonic monasters.

- Figs. 4, 5. Lateral views of synapsis stages, only a few of the chromatin elements shown.
 Fig. 6. Nucleus, synapsis, showing two whole bivalent chromosomes.
 Fig. 7. One whole bivalent chromosome, end of the synapsis stage.
 Figs. 8, 9. Postsynapsis stages, in each three whole bivalent chromosomes shown.
 Fig. 10. Telophase of the spermatocyte, showing two whole bivalent chromosomes.
 Fig. 11. Late telophase, showing eight bivalent chromosomes.
 Fig. 12. Rest stage of spermatocyte.
 Figs. 13, 14. Early prophases of first maturation division, each figure showing two whole bivalent chromosomes.
 Fig. 15. Two whole bivalent chromosomes, a little later stage than the preceding, showing their linin connections.
 Figs. 16, 17. Later prophases, only in Fig. 16 are all bivalent chromatin elements shown; in Fig. 17 the centrosome pairs on the surface of the nucleus.
 Fig. 18. Lateral view of the monaster of the first maturation mitosis, all chromatin elements shown.
 Fig. 19. Pole view of the same stage.

Euchistus tristigmus, Figs. 20-26.

- Fig. 20. Pole view of spermatogonic monaster.
 Figs. 21, 22. Nuclei of first spermatocytes, rest stage.
 Figs. 23, 24. Pole views of monaster, first maturation division.
 Fig. 25. Lateral view of spindle, first maturation division (showing all chromatin elements).
 Fig. 26. Second spermatocyte, chromatin elements not definitely arranged in the equator of the spindle.

Podisus spinosus, Figs. 27-29.

- Fig. 27. Pole view of spermatogonic monaster.
 Fig. 28. Telophase of first spermatocyte, nucleus.
 Fig. 29. Pole view of monaster, first maturation mitosis.

Mormidea lugens, Figs. 30-33.

- Fig. 30. Nucleus of spermatogonium, commencement of prophase.
 Fig. 31. Pole view of spermatogonic monaster.
 Fig. 32. Nucleus, postsynapsis stage.
 Fig. 33. Pole view of monaster, first maturation mitosis.

Peribolus limbolaris, Figs. 34-37.

- Fig. 34. Spermatogonic nucleus, rest stage.
 Fig. 35. Pole view of spermatogonic monaster.
 Fig. 36. Nucleus of first spermatocyte, rest stage.
 Fig. 37. Pole view of monaster, first maturation mitosis.

Cosmopepla carnifex, Figs. 38-41.

- Fig. 38. Pole view of spermatogonic monaster.
 Fig. 39. Nucleus of first spermatocyte, rest stage.
 Fig. 40. Lateral view of the spindle, first maturation mitosis, showing all chromatin elements.
 Fig. 41. Pole view of the same stage.

Nezara hilaris, Figs. 42-45.

- Figs. 42, 43. Spermatogonic nuclei, commencement of prophase.
 Fig. 44. Pole view of spermatogonic monaster.
 Fig. 45. Nucleus of first spermatocyte, early telaphase.

Brochymena sp., Figs. 46-49.

Fig. 46. Spermatogonic nucleus, rest stage.

Fig. 47. Pole view of spermatogonic monaster.

*Plate II.**Brochymena* sp., Figs. 48, 49.

Fig. 48. Nucleus of first spermatocyte, telaphase.

Fig. 49. Pole view of monaster, first maturation mitosis.

Perillus confluens, Figs. 50-53.

Fig. 50. Spermatogonic nucleus, rest stage.

Fig. 51. Spermatogonic monaster, pole view.

Fig. 52. Nucleus of first spermatocyte, rest stage.

Fig. 53. Pole view of monaster, first maturation mitosis.

Cænus delius, Figs. 54-63.

Fig. 54. Spermatogonic nucleus, rest stage.

Fig. 55. Spermatogonic monaster, pole view.

Figs. 57, 58. Nuclei of first spermatocytes, rest stage.

Figs. 59, 60. Pole views of monasters, first maturation mitosis.

Fig. 61. Lateral view of the same stage, showing all the chromatin elements.

Fig. 62. Pole view of monaster, first maturation mitosis.

Fig. 63. Nucleus of first spermatocyte, rest stage.

Trichopepla semiovittata, Figs. 64-69.

Fig. 64. Spermatogonic nucleus, rest stage.

Fig. 65. Spermatogonic monaster, pole view.

Fig. 66. Nucleus of first spermatocyte, synapsis.

Fig. 67. Nucleus of first spermatocyte, rest stage.

Fig. 68. Pole view of monaster, first maturation mitosis.

Fig. 69. Lateral view of slightly earlier stage, showing all the chromatin elements.

Eurygaster alternatus, Figs. 70, 71.

Fig. 70. Nucleus of first spermatocyte, rest stage.

Fig. 71. Pole view of monaster, first maturation mitosis.

Anasa tristis, Figs. 72-76.

Figs. 72, 73. Spermatogonic nuclei, rest stage.

Fig. 74. Spermatogonic monaster, pole view.

Fig. 75. Nucleus of first spermatocyte, telaphase

Fig. 76. Pole view of monaster, first maturation mitosis.

Anasa armigera, Figs. 77, 78.

Fig. 77. Spermatogonic monaster, pole view.

Fig. 78. Pole view of the spindle of the first maturation division, the chromatin elements not yet definitely arranged in the plane of the equator.

Anasa sp., Figs. 79-83.

- Fig. 79. Spermatogonic nucleus, rest stage.
 Fig. 80. Spermatogonic monaster, pole view.
 Fig. 81. Nucleus of first spermatocyte, rest stage.
 Fig. 82. Pole view of monaster, first maturation division.
 Fig. 83. Lateral view of four bivalent chromosomes, monaster stage of first maturation mitosis, the poles of the spindle outside of the plane of the section.

Metapodius terminalis, Figs. 84-87.

- Fig. 84. Spermatogonic nucleus, rest stage.
 Fig. 85. Spermatogonic monaster, pole view.
 Fig. 86. Nucleus of first spermatocyte, telaphase.
 Fig. 87. Pole view of monaster, first maturation mitosis.

Chariesterus antennator, Figs. 88-90.

- Fig. 88. Nucleus of first spermatocyte, telaphase.
 Fig. 89. Lateral view of monaster stage of the first maturation mitosis, showing all the chromatin elements.
 Fig. 90. Pole view of the same stage.

Alydus pilosulus, Figs. 91-95.

- Fig. 91. Spermatogonic-nucleus, rest stage.
 Fig. 92. Spermatogonic monaster, pole view.
 Figs. 93, 94. Nuclei of first spermatocytes, rest stage.
 Fig. 95. Pole view of monaster, first maturation mitosis.

Plate III.

Alydus eurinus, Figs. 96-102.

- Fig. 96. Spermatogonic monaster, pole view.
 Fig. 97. Nucleus of first spermatocyte, telaphase.
 Fig. 98. Pole view of monaster, first maturation mitosis.
 Fig. 99. Lateral view of the same stage.
 Fig. 100. Pole view of monaster, second maturation mitosis.
 Figs. 101, 102. Spermatids at close of second maturation mitosis.

Corizus lateralis, Figs. 103-106.

- Fig. 103. Nucleus of first spermatocyte, telaphase.
 Figs. 104, 105. Pole views of monasters, first maturation mitosis.
 Fig. 106. Oblique view of the spindle of the first maturation mitosis, before the chromosomes have taken their definite position in the equator.

Harmostes reflexulus, Figs. 107-117.

- Fig. 107. Spermatogonic nucleus, rest stage.
 Figs. 108-110. Spermatogonic monasters, pole views.
 Fig. 111. Nucleus of first spermatocyte, rest stage.
 Fig. 112. Pole view of monaster, first maturation mitosis.
 Fig. 113. Lateral view of the same stage, showing all the chromatin elements.

Figs. 114, 115. Pole views of monasters, first maturation mitosis.

Fig. 116. Lateral view of the same stage, showing all the chromatin elements.

Fig. 117. Pole view of spermatid at the close of the second maturation division.

Protenor belfragei, Figs. 118-141.

Fig. 118. Spermatogonic nucleus, early prophase.

Figs. 119-123. Spermatogonic monasters, pole views.

Fig. 124. Nucleus of first spermatocyte, synapsis.

Figs. 125-128. Lateral views of the large chromosome *x*, from nuclei in the late synapsis stage.

Figs. 129, 130. Nuclei of first spermatocytes, telophase.

Figs. 131-134. Nuclei of first spermatocytes in successive prophases.

Figs. 135, 136. Lateral views of successive monaster stages, first maturation mitosis, all the chromatin elements shown in Fig. 135.

Fig. 137. Pole view of the stage of Fig. 136.

Fig. 138. Lateral view of the anaphase, first maturation mitosis.

Fig. 139. Pole view of second spermatocyte, chromosomes not definitely arranged in the equator of the spindle.

Fig. 140. Lateral view of anaphase, second maturation mitosis.

Fig. 141. Still later anaphase.

Plate IV.

Cymus augustatus, Figs. 142-144.

Fig. 142. Lateral view of monaster, first maturation mitosis.

Fig. 143. Pole view of one daughter cell (second spermatocyte) of the dyaster stage of the first maturation mitosis, the univalent chromatin elements seen laterally.

Fig. 144. Pole view of one chromosome plate, metakinesis of first maturation mitosis, chromatin elements seen on end view, except the one marked *a*.

Ichnodemus falicus, Figs. 145-148.

Fig. 145. Spermatogonic monaster, pole view.

Fig. 146. Nucleus of first spermatocyte, late prophase, showing all the chromatin elements.

Figs. 147, 148. Pole views of monasters, first maturation mitosis, in Fig. 148 two of the chromosomes viewed laterally.

Peliopelta abbreviata, Figs. 149-151.

Fig. 149. Spermatogonic monaster, pole view.

Fig. 150. Pole view of monaster, first maturation mitosis.

Fig. 151. Lateral view of same stage, two of the large chromosomes not shown.

Eldancala dorsalis, Figs. 152-158.

Fig. 152. Spermatogonic nucleus, rest stage.

Figs. 153, 154. Spermatogonic monasters, pole views.

Fig. 155. Nucleus of first spermatocyte, rest stage.

Fig. 156. Pole view of monaster, first maturation mitosis.

Fig. 157. Lateral view of the same stage, three of the chromosomes not shown.

Fig. 158. Lateral view of the anaphase, first maturation mitosis

Oncopeltus fuscatus, Figs. 159-171.

Fig. 159. Spermatogonic nucleus, early prophase.

Fig. 160. Spermatogonic monaster, pole view.

Figs. 161-165. Nuclei of first spermatocytes, rest stage.

Fig. 166. Nucleus of first spermatocyte, late prophase, showing all the chromatin elements.

Figs. 167, 168. Pole views of monasters, first maturation mitosis.

Fig. 169. Lateral view of same stage, five of the chromosomes not shown.

Fig. 170. Lateral view of anaphase, first maturation mitosis.

Fig. 171. Pole view of second spermatocyte, chromatin elements not definitely arranged in the equator of the spindle.

Leptopterna dolabrata, Figs. 172-176.

Figs. 172-175. Nuclei of first spermatocytes, growth period.

Fig. 176. Pole view of monaster, second (?) maturation mitosis.

Calocoris rapidus, Figs. 177-188.

Fig. 177. Spermatogonic monaster, pole view.

Figs. 178-180. Nuclei of first spermatocytes, telaphase.

Fig. 181. Oblique lateral view of the spindle before the chromosomes are arranged in the plane of the equator, first maturation mitosis.

Figs. 182-184. Oblique lateral views of monasters, first maturation mitosis.

Figs. 185, 186. Pole views of the same stage.

Figs. 187, 188. Pole views of monasters, second maturation mitosis.

Pæcilocapsus lineatus, Figs. 189, 190.

Fig. 189. Nucleus of first spermatocyte, early telaphase.

Fig. 190. Pole view of monaster, first maturation mitosis.

Plate V.

Pæcilocapsus goniphorus, Figs. 191-198.

Figs. 191-195. Nuclei of first spermatocytes, rest stage.

Figs. 196, 197. Pole views of monasters, first maturation mitosis.

Fig. 198. Lateral view of the same stage.

Phymata sp., Figs. 199-203.

Fig. 199. Spermatogonic nucleus, rest stage.

Fig. 200. Spermatogonic monaster, pole view.

Fig. 201. Nucleus of first spermatocyte, telaphase.

Fig. 202. Pole view of monaster, first maturation mitosis.

Fig. 203. Lateral view of same stage.

Coriscus fesus, Figs. 204-206.

Figs. 204, 205. Nuclei of first spermatocytes, telaphase and rest stages respectively.

Fig. 206. Pole view of first spermatocyte, the chromosomes not definitely arranged in the plane of the equator of the spindle.

Acholla multispinosa, Figs. 207-211.

Fig. 207. Spermatogonic monaster, pole view.

Figs. 208, 209. Nuclei of first spermatocytes, early prophase.

Fig. 210. Pole view of monaster, first maturation mitosis.

Fig. 211. Pole view of monaster, second maturation mitosis.

Sinea diadema, Figs. 212-218.

Figs. 212, 213. Nuclei of first spermatocytes, telaphase.

Figs. 214, 215. Pole views of monasters, first maturation mitosis.

Fig. 216. Lateral view of the plurivalent chromosome of the first maturation mitosis, showing the mantle fibre attachments.

Figs. 217, 218. Lateral views of successive anaphases, first maturation mitosis.

Limnobates lineata.

Fig. 219. Nucleus of first spermatocyte, rest stage.

Prionidus cristatus, Figs. 220-225.

Figs. 220-222. Spermatogonic nuclei, rest stage.

Figs. 223, 224. Spermatogonic monasters, pole views.

Fig. 225. Nucleus of first spermatocyte, rest stage.

Milyas cinctus, Figs. 226-228.

Figs. 226-228. Nuclei of first spermatocytes, rest stage.

Hygotrechus sp., Figs. 229-231.

Fig. 229. Spermatogonic monaster, pole view.

Fig. 230. Nucleus of first spermatocyte, synapsis stage.

Fig. 231. Pole view of monaster, first maturation mitosis.

Limnotrechus marginatus, Figs. 232, 233.

Fig. 232. Nucleus of first spermatocyte, rest stage.

Fig. 233. Pole view of monaster, first maturation mitosis.

Pelocoris femorata.

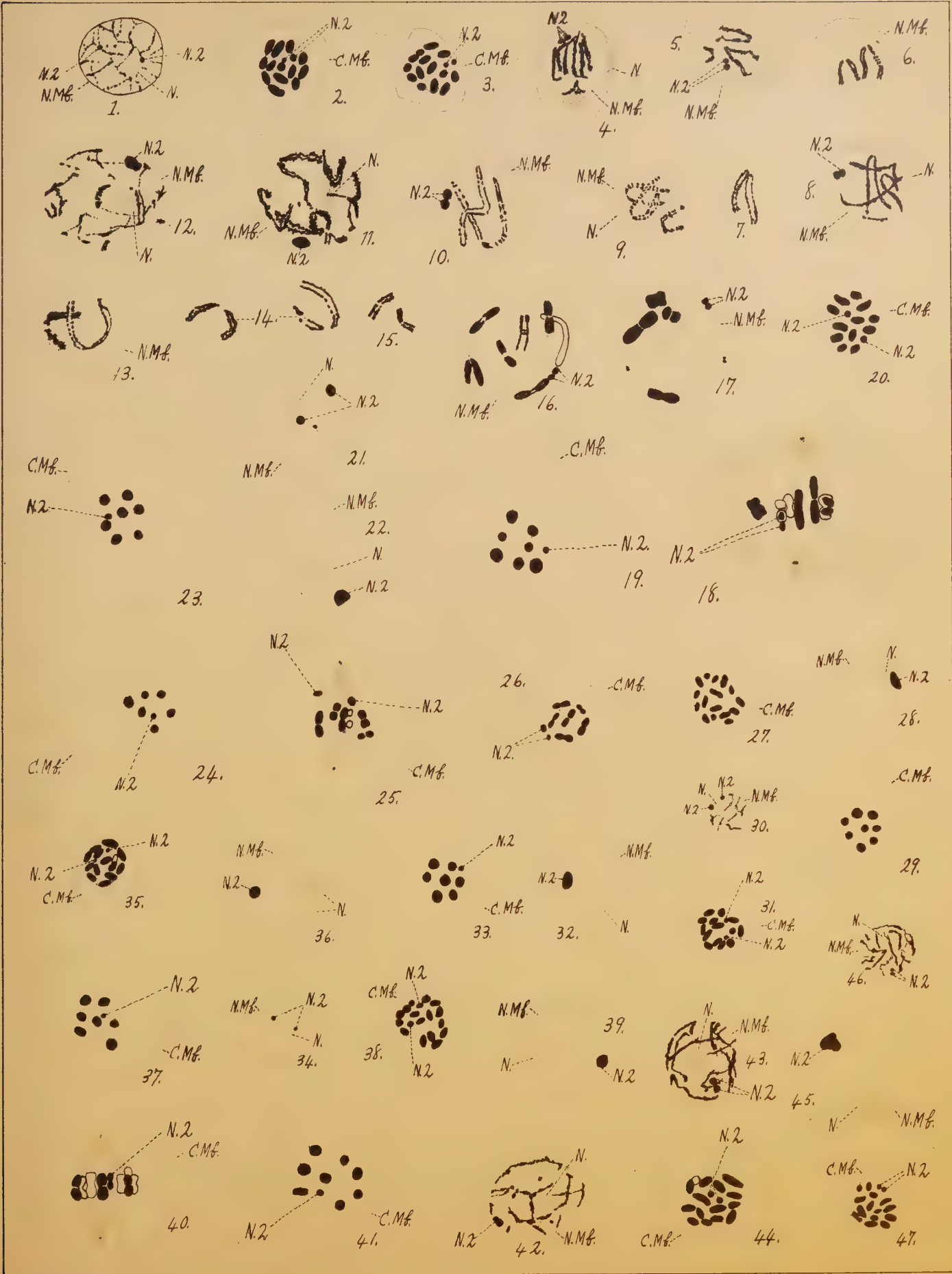
Fig. 234. Spermatogonic monaster, pole view.

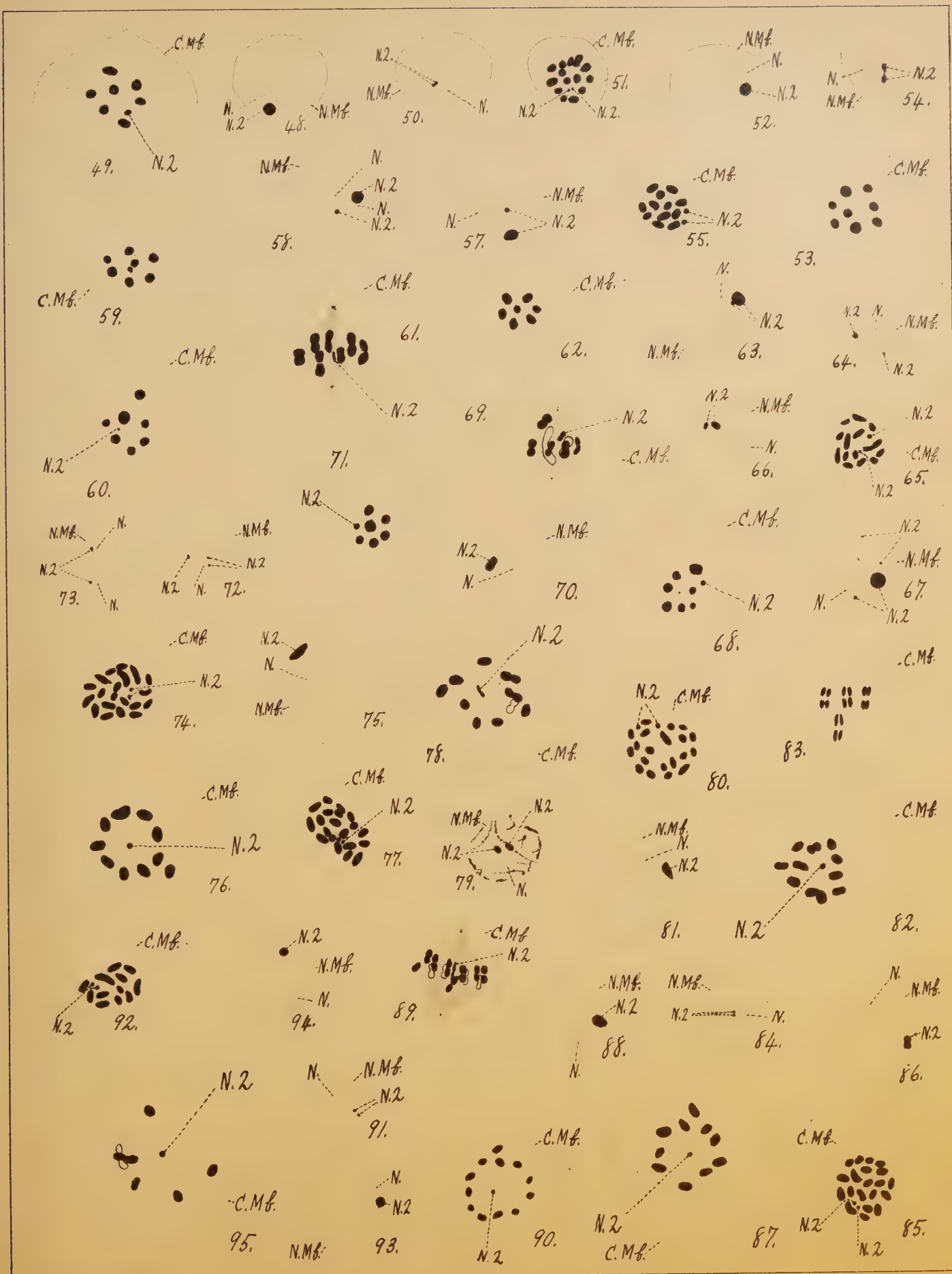
Zaitha sp., Figs. 235-238.

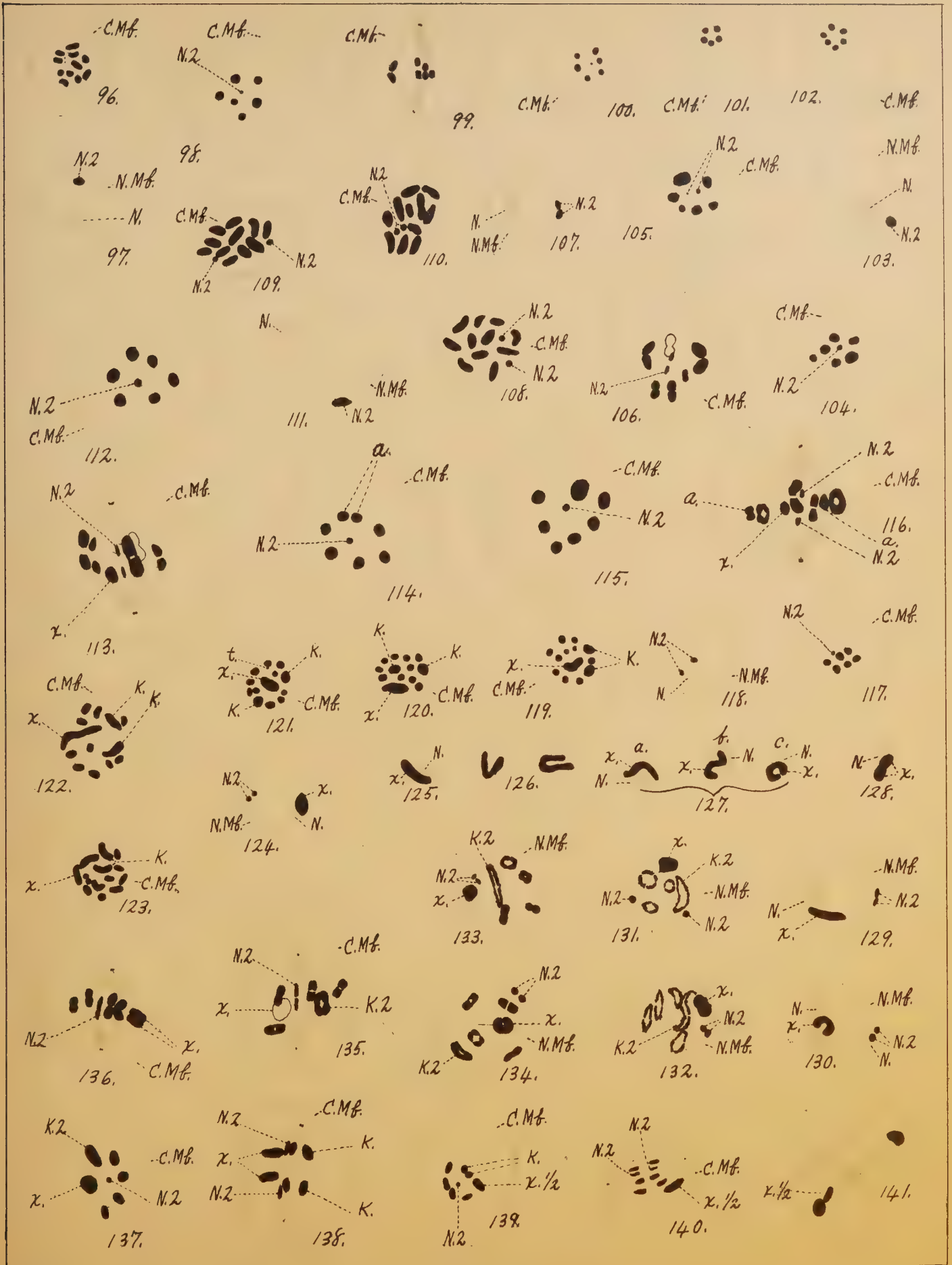
Fig. 235. Spermatogonic nucleus, rest stage.

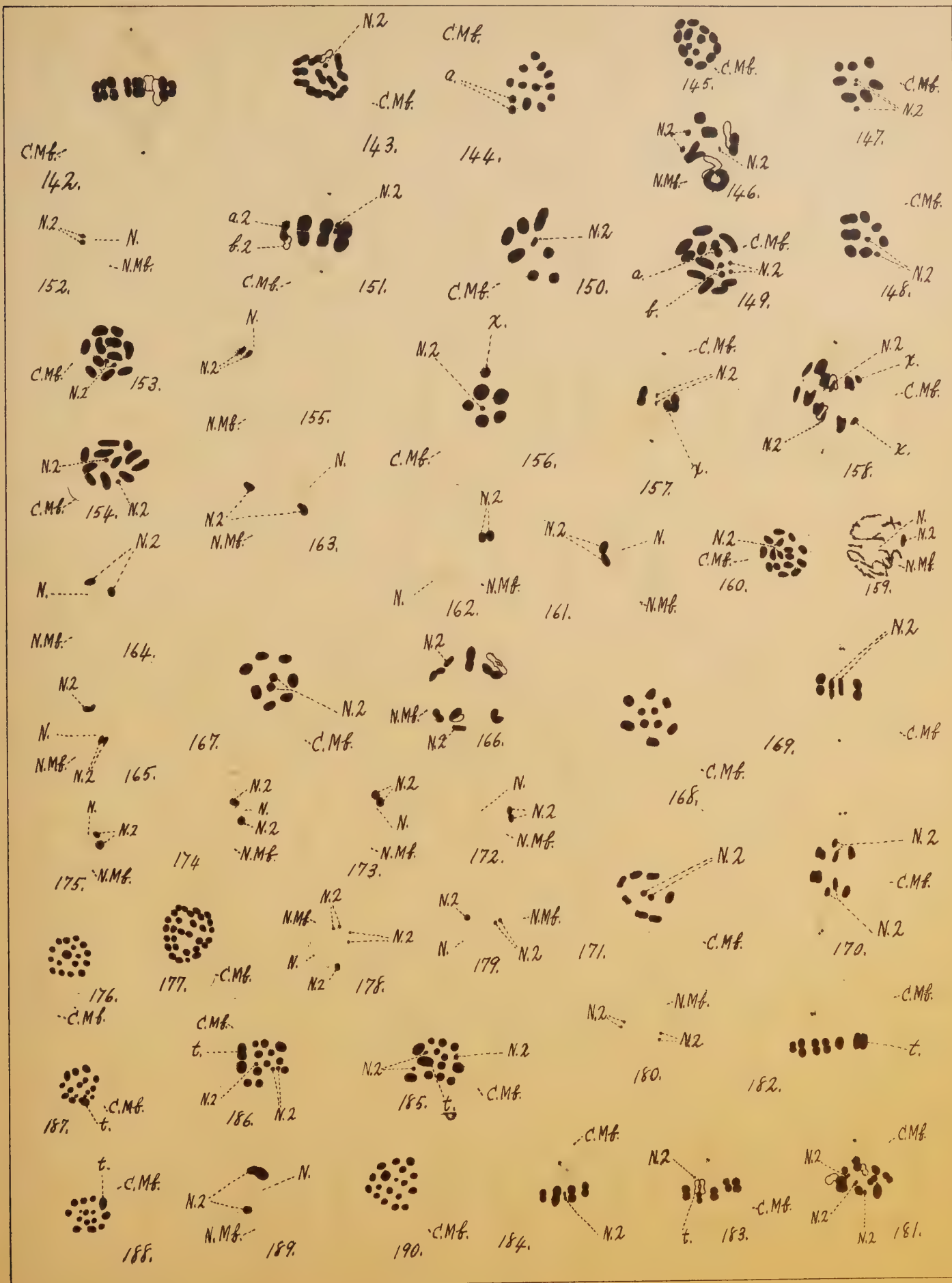
Figs. 236, 237. Spermatogonic monasters, pole views.

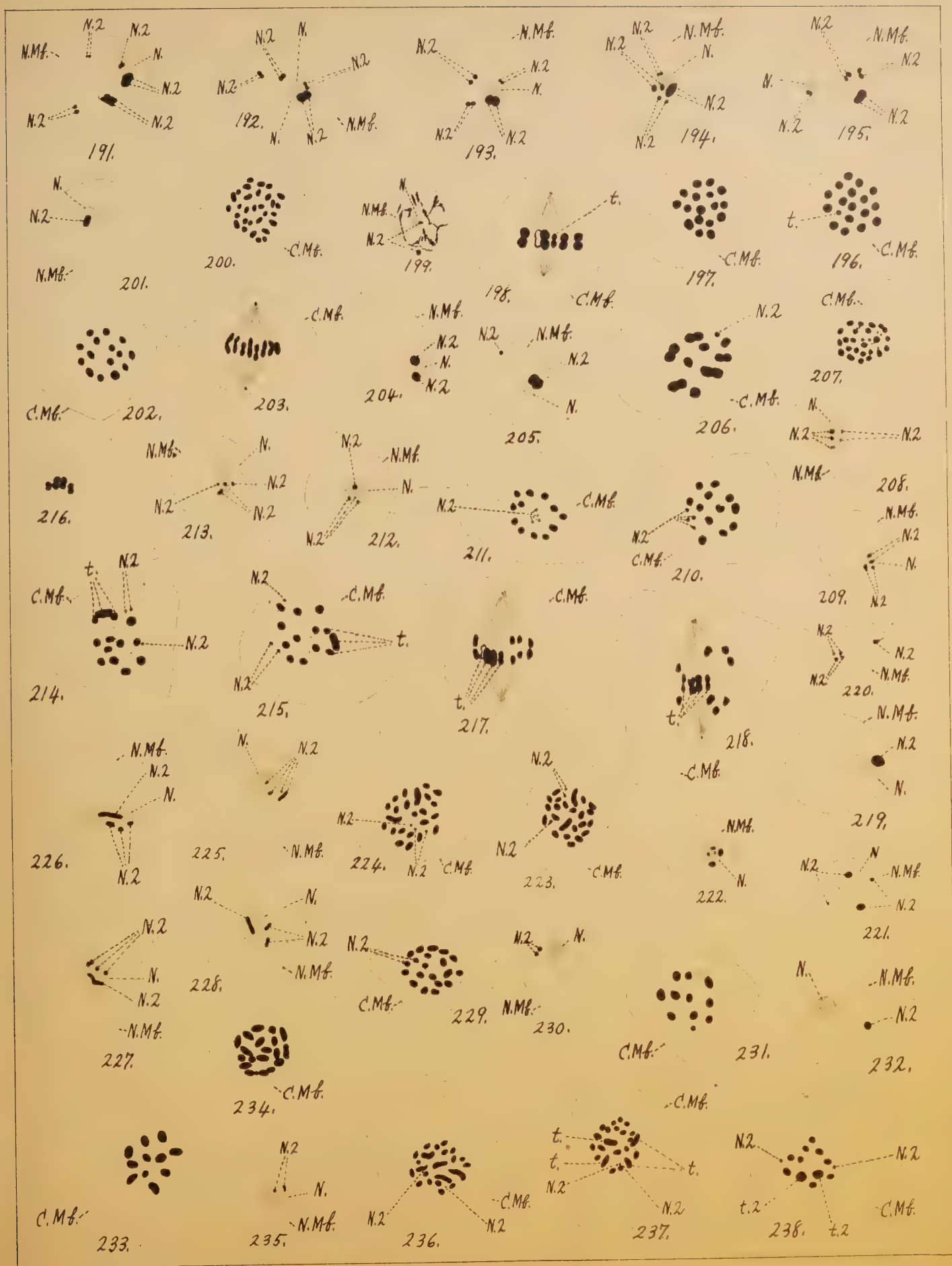
Fig. 238. Pole view of monaster, first maturation mitosis.











ARTICLE V.

FOSSIL MAMMALIA OF THE WHITE RIVER BEDS OF MONTANA.

BY EARL DOUGLASS.

(Read May 3, 1901.)

Since writing my paper on the Tertiary deposits of western Montana (1899)* further explorations have been made and many valuable fossils secured. Part of these fossils have been studied under more favorable circumstances, so that interesting additions can now be made to our knowledge of these beds.

In June, 1899, Prof. F. D. Smith, of the University of Montana, and myself started eastward from Missoula with team and camping outfit, he to collect geological specimens for the University and I to make further explorations in the Tertiary deposits, and to add, if possible, to my collection of fossil mammals. Nearly all of my previous collecting had been done east of the main divide or watershed of the Rocky Mountains. I had found that Tertiary deposits occurred in the valleys of Flint and Deer Lodge creeks, and it was hoped that enough fossils might be obtained to determine the horizons of these beds and their relation to those east of the divide.

In the valley of Flint creek, south of Drummond, near the village of New Chicago, the upper deposits were found to contain, in a limited area, quite an abundance of valuable Loup Fork fossils. The exact relation of these beds to those of other localities is still a matter of doubt. The strata and the occurrence of the fossils are almost exactly as in the upper Deep River beds. This is not true of any other deposits I have seen. The bones, as a rule, are in nodules in cream-colored clays. The species seem to be mostly new, but have not been thoroughly studied. Some of the most interesting specimens are a strange animal which had a proboscis and was related to *Merycochærus*, a hog-like animal, the first found in America, and a skull of the so-called *Blastomeryx*, of the *B. borealis* type, with a mandible, proving that it is *Palæomeryx*. Nearly all parts of the skeleton of *Palæomeryx* were found. The *Merycochærus*-like animal I have described

* See list of works on page 279.

under the name of *Merycochoerus laticeps* (1900); but since seeing the skulls of this genus in the American Museum of Natural History, I am inclined to think it will have to be given a new generic name. Both of these are vastly different from the John Day forms, *Promerycochoerus*, that have been put in this genus.

The beds underlying these look like some of the Oligocene east of the main divide. They are light colored. There are layers of limestone containing fresh-water snails. In one place there were thinly laminated shales with a few fish remains.

A few miles to the northeast, on the north side of the Hell Gate river, in gray sandy bluffs, the skulls of a dog much like *Temnocyon*, a *Leptomeryx*, and an Oreodont were discovered. These beds may be John Day.

Before going to a new field Prof. Smith was called away and Mr. Homer McDonald, a student of the University, accompanied me during the remainder of the time. After obtaining a few remains of a large rhinoceros, a large camel, and some poorly preserved mastodon teeth from the later Tertiary in the Deer Lodge valley, we crossed the divide southwest of Butte.

Near Whitehall, at two localities on Pipestone creek, one near Pipestone Springs and one on a branch called the Little Pipestone, were limited exposures where many small bones, teeth, and fragments of jaws were found. These were associated with distinguishable *Titanotherium* remains which were not of the largest species.

After making a valuable collection here we moved eastward, examining the Tertiary deposits on the North Boulder and obtaining jaws and teeth of a *Protohippus*.

Northwest of Three Forks are gray beds composed of fine material containing lime and looking much like the beds on Pipestone creek. There are also layers of hard limestone which break into angular fragments. Here there were a good many *Titanotherium* remains. We obtained large parts of two skeletons and other bones. Some interesting little Oreodonts, including a little *Agriochærus*, were obtained, descriptions of which will be found in this paper.

Last spring (June, 1900) I again started from Missoula, going up the Big Blackfoot river, hoping to find Tertiary deposits on this river or on Nevada creek, one of its principal branches. The country around Ovando is covered with glacial drift, but on the road from that place to Helmville, near where it crosses the Big Blackfoot, the drift becomes thin and finally vanishes. The river cuts into the Tertiary deposits, in some places making quite high bluffs. I found no fossils here except wood fragments, but the beds are undoubtedly Oligocene (White River or John Day). After passing through a quite long cañon in going southeast up Nevada creek, the Tertiary appears again. The rock is mostly soft, but in places thousands of flint fragments have weathered out and are scattered over the surface. In some of these there are fossil snails. A few miles north of

Avon some bone fragments were found, which confirmed the belief that these beds are Oligocene.

After crossing a basaltic lava flow south of Avon the Tertiary beds appear again, but the fossils obtained here, as previously stated, are of later date, being either Miocene or Pliocene. Continuing my course southward I found that south of Silver Bow, as had been mistrusted, the lake bed deposits were continuous across the main divide. It is evident that previous to Miocene times a river had carved out a broad valley across what is now the watershed that divides the waters of the Atlantic from those of the Pacific; so the divide then occupied a different position from what it does now. In Tertiary times, probably by the formation of a great lake, this valley was partly filled with sediment, and after the drying up of the lake the drainage was changed. It is very probable that at some time during the Tertiary a lake extended from the northern part of the Deer Lodge valley southward to the Big Hole, eastward to the Jefferson, then northeastward to the Missouri river and down the Missouri to the region of Helena, a distance of 180 miles. There is no barrier and it is evident that there was none, and the Tertiary deposits can be traced the greater portion of the way. This, of course, may have happened more than once. A little south of the divide, on Divide creek, part of the skull and skeleton of a small horse was obtained.

There are only three regions from which fossils have been secured sufficiently abundant and characteristic, so that it can be positively stated now that the strata are White River; but there are other regions that are only a little doubtful. I believe that the White River, like the Loup Fork, occurs in all the principal valleys of southwestern Montana.

There is some doubt concerning the John Day. The lower Deep River beds near White Sulphur Springs appear to belong to that age (Scott, 1893), and some fossils in my collection, especially those obtained east of Drummond, appear to be more like John Day than White River, but there are not enough to settle the question.

The three regions that are certainly White River are: (1) on Pipestone creek, (2) on Thompson creek northwest of Three Forks, and (3) northeast of Toston near Cottonwood creek. Those on Blacktail Deer creek are probably White River. For convenience, until the strata in the different localities are satisfactorily correlated, I will give them local names.

WHITE RIVER OLIGOCENE.

Pipestone Beds.

These are on Pipestone creek at two localities, one on the Big Pipestone near Pipestone Springs and the other on a branch, the Little Pipestone. The first is north of west and







EXPLANATION OF MAP.

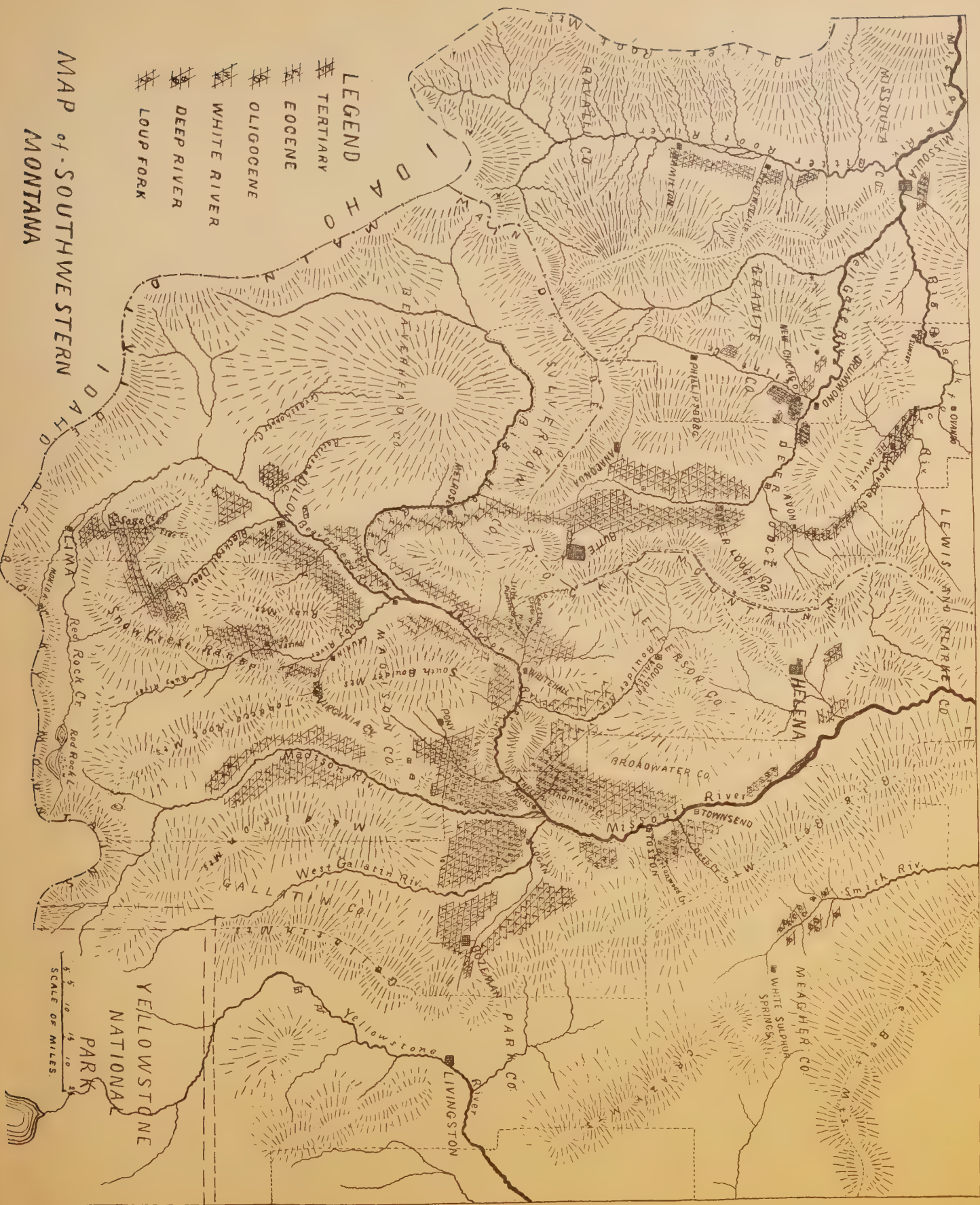
The map shows only approximately the Tertiary areas, as their limits have not been mapped or accurately defined. I have personally observed the Tertiary deposits in all the regions in which they are indicated, except in the small areas in the Yellowstone valley.

Where there is doubt as to the subdivisions the general term Tertiary has been used. By Oligocene, White River or John Day is meant. In the small spot marked Eocene (?), near Lima, fossils were found, but they appear so contradictory that it was thought best not to publish descriptions of the fossils until the beds were reëxamined and a solution of the problem found.

Places marked W ? L ? etc., indicate that the beds are doubtfully White River, Loup Fork, etc.

MAP of SOUTHWESTERN MONTANA

- LEGEND**
-  TERTIARY
 -  EOCENE
 -  OLIGOCENE
 -  WHITE RIVER
 -  DEEP RIVER
 -  LOUP FORK



YELLOWSTONE
NATIONAL
PARK

SCALE OF MILES.
0 5 10 15 20

the second south of west of Whitehall, in Jefferson county. The strata containing the bones are a sandy clay that swells and cracks on weathering and crackles under the feet when dry, and a light-gray fine-grained homogeneous material. Under the microscope the latter shows many angular, glassy fragments, which are undoubtedly volcanic dust. The fossils have not all been determined. Most of them are new. The following is a partial list:

<i>Ictops acutidens</i> , sp. nov.	<i>Palæolagus turgidus</i> (?) Cope.
<i>Eumys minor</i> , sp. nov.	<i>Hyaenodon minutus</i> , sp. nov.
<i>Cylindrodon fontis</i> , gen. et sp. nov.	<i>Agriochærus maximus</i> , sp. nov.
<i>Sciurus jeffersoni</i> , sp. nov.	<i>Mesohippus bairdi</i> (?)
<i>Ischyromis typus</i> Leidy.	<i>Leptochærus</i> .
<i>Palæolagus temnodon</i> , sp. nov.	<i>Leptomeryx</i> .
<i>Palæolagus triplex</i> (?) Cope.	<i>Hyracodon</i> .

Thompson Creek Beds.

These are well exposed on a creek draining a small region northwest of Three Forks. The stream is small and nearly dry in summer, and I do not know that it is named on any map, but I have called it Thompson creek from the only man who lives near it. If they were called Three Forks beds they would be confused with the Three Forks formation which is Devonian. In these beds are the cracking clays above mentioned as occurring on Pipestone creek, also light colored material resembling that occurring at that place but containing lime. There are layers of limestone and strata of hard sandstone.

Most of the fossils were found on the north branch of Thompson creek near the road to Boulder. Farther to the southwest are large quantities of fossil wood, but only occasional bone fragments. The most abundant vertebrate remains are bones of Titanotheres. These have not been studied, but they do not belong to the largest species.

List of Fossils.

<i>Limnenetes platyceps</i> , gen. et sp. nov.	<i>Mesohippus</i> .
<i>Limnenetes</i> (?) <i>anceps</i> , sp. nov.	<i>Colodon</i> .
<i>Agriochærus minimus</i> , sp. nov.	<i>Titanotherium</i> .

Toston Beds.

These are exposed northeast of Toston, which is a small railroad station on the Missouri river below Three Forks and above Townsend. They are about twenty-five miles north and east of the Thompson Creek beds. While the last named deposits apparently belong to the lower White River or Titanotherium horizon, part, at least, of these seem to

more nearly correspond to the Oreodon division. Among the fossils are three very good skulls of Oreodonts. One I have referred to the genus *Eucrotaphus*, one is a new species of Oreodon and one is much like *O. culbertsoni*. A good portion of the skeleton of the latter was found, but there has not been time to clean it and make careful comparisons. It is probable that it will have to be referred to a new species.

These and other Oreodont remains were in the cracking, sandy clays which contain nodular layers. A *Titanotherium* tooth was found in the same kind of clay but perhaps a trifle lower down. *Colodon* and *Hyænodon* teeth and jaws were obtained, but I cannot state with certainty their relation to the beds above mentioned. The strata here are considerably disturbed, and in some places dip to the eastward as much as 30° to 40°. In the ardent work of collecting I had not the time to study the geology of the region as much as I hope to do later. Lying unconformably on these deposits in places are nearly horizontal strata of later date, either Miocene or Pliocene.

List of Fossils.

<i>Hyænodon montanus</i> , sp. nov.	<i>Colodon</i> , sp.
<i>Oreodon robustum</i> , sp. nov.	<i>Mesohippus</i> .
<i>Eucrotaphus helencæ</i> , sp. nov.	<i>Titanotherium</i> .
<i>Colodon cingulatus</i> , sp. nov.	<i>Cænopus</i> (?).

The Blacktail Deer Creek Beds.

These are on Blacktail Deer creek, about thirty miles south and east of Dillon. The exposure is small and only a few fossils were found. The material, as in the localities previously mentioned, is mostly light colored and fine grained, yet there are thin strata of sandstone. None of the fossils positively determine the horizon. There was the new genus *Arretotherium*, part of the back of a skull of *Cænopus* about the size of *Aceratherium tridactylum* Osborn, and part of a mandible of *Steneofiber hesperus* sp. nov. which is described in this paper.

List of Fossils.

<i>Steneofiber hesperus</i> , sp. nov.	<i>Arretotherium acridens</i> , gen. et sp. nov.
<i>Cænopus</i> (?).	

The skull of *Steneofiber complexus*, described in this paper, came from the beds on the west side of the Madison river above Three Forks (Douglass, 1899, p. 4). The locality is about fifteen miles south of where the fossils occur in the Thompson Creek beds. Near the same place were a femur, tibia, fibula and calcaneum of a rather long-limbed *Perissodactyl*, probably a rhinoceros, but the deposits here contain very few fossils.

There are turtle remains in all the beds above described.

Besides the above there are at least three localities where fragments of fossils that are almost certainly White River have been collected. They are north of Avon in Deer Lodge county, at Glendale in Beaverhead county, and west of Puller Springs near the Ruby river in Madison county.

In Montana vertebrate fossils of the Tertiary have not been found in anything like abundance except at two or three restricted localities, and these long distances apart, though a few have been found in as many as twenty different places. In the White River they were the most numerous on Pipestone creek, but they are mostly isolated teeth, jaws and other bones of small animals. Certain strata are quite rich in fossils, but on account of their dip and their being, as a rule, covered with vegetation or débris, they are exposed for only short distances. It is curious, though, that in all the beds in which collecting has been done surprisingly few duplicates have been obtained, and few of the things have been found anywhere else. The White River collection, as it has been studied and compared with those of other regions, has caused continual surprise on account of its great difference from them. The explanation seems to lie partly in the fact that in Montana we have quite a rich fauna from a horizon nearly or quite corresponding to the lower White River or Titanotherium beds of South Dakota, where few fossils except Titanotheres have been found. Though the fossils were scattered over a large area (about 150 by 170 miles) and were not especially abundant, yet during the six years that I spent in Montana a good-sized collection was secured.

Most of my time while in the field has been employed in the search for fossils, and I have never seen the corresponding Tertiary formations in other regions, yet I have made some observations that may be interesting. W. D. Matthews' paper, "Is the White River Tertiary an Æolian Deposit?" (*Amer. Nat.*, May, 1899), has added new interest to the study of these so-called lake bed deposits. There certainly is much mystery concerning their origin and the way in which the animal remains became fossilized. The fossils from Montana are different in appearance and are enclosed in a different matrix from those that are found in South Dakota. As has been said of the former (referring to color, etc.), "They do not look like White River fossils."

Most of the material in the beds that are undoubtedly White River is light colored, fine grained, and soft, though there are some layers of coarser and harder material. The same is true of the beds that, from their lithological characters and imperfect fossils, have been supposed to belong to the same horizon. The nearness or distance of the shore or the mountains and the character of the contiguous rocks seem to have little influence on the character or composition of the sediments.

I have made microscopic examination of samples from the several fossil-bearing beds, and all contain minute fragments undistinguishable from the glass fragments from the

beds of pure volcanic dust in the Loup Fork of Montana. It is very likely that the greater part of the deposits are a mixture of clay, fine sand and volcanic dust, with an abundance of calcareous matter in some places. Often, as previously stated, there are strata of limestone. In many places this limestone contains an abundance of fresh-water shells. These have not yet been specifically determined. Sometimes for a considerable thickness there is no distinct stratification, and in other places there are thin layers and distinct lamination. Near New Chicago, in thinly laminated shales, a few fish remains were found, and a little distance away, in a harder layer, fragments of bone, including part of a metapodial of an Oreodont associated with snails.

If the beds that do not contain fossil mammals, but have the same appearance as those that do contain them, are of the same age as the latter, there was a large area of deposition in Montana.

There has been considerable disturbance since the deposition of the White River beds, for in some places the strata dip at a high angle. I have not seen any distinct shore markings except in the vicinity of Missoula, where there was undoubtedly a lake in Pleistocene times.

The work on this paper has been done in the Museum of Princeton University, to which the greater part of my collection has been removed for study. It is due to the broad-minded interest of Prof. W. B. Scott that I have been enabled to do the work under such favorable circumstances, and his intelligent criticism has been of the greatest value to me. Dr. Marcus S. Farr, the Curator of Vertebrate Palæontology, has given me free access to the Museum and helped me in every possible way. The drawings of fossils were made by Mr. F. Von Iterson. The map was drawn by myself.

All the specimens described in the paper were found in Montana by myself and they are now in my collection, to which the numbers in the text refer.

PRINCETON MUSEUM, May 2, 1901.

DESCRIPTIONS OF SPECIES.

Ictops acutidens, sp. nov.

The type, No. 36 of my collection, consists of portions of a skull, mandible and other bones with a nearly complete femur, astragalus, calcaneum and one lumbar vertebra. It was a young individual. The epiphyses are free and the last lower premolar erupting. I do not know whether the last two upper premolars are permanent or temporary, but will describe them as they are.

If full grown the animal was smaller than *I. dakotensis** and differs from it in several

* Compared with specimen in the American Museum of Natural History.

respects. P^3 is much larger and more complex, but it may be a temporary tooth. There are quite prominent antero-external cusps on the last two premolars and the first two molars.

Superior Dentition.— P^3 has four sharp cusps, three of which—the protostyle, protocone and tritocone—are in an antero-posterior line. The protocone is the largest and is high and pointed. The tritocone is larger than the protostyle. The deuterocone is opposite the interval between the protocone and tritocone. This tooth is the longest of those that are preserved in the upper jaw.

P^4 , like the molars, is wider than long. It has four primary cusps—the protocone, tritocone, deuterocone and tetartocone—and three secondary ones—a protostyle and an anterior and a posterior median conule. The protocone and tritocone are high and pointed, the first being slightly the higher. The tetartocone is prominent but not high. The protostyle forms a small but distinct antero-external cusp. The protoconule and metaconule are plainly distinguishable (with a lens) on the protoloph and metaloph.

M^1 is almost like P^4 except that it is wider and the protoconule is merged into the protoloph which passes from the protocone to the parastyle. The metaconule is distinguishable. There is a small metastyle. M^2 is wider than M^1 but not so long. There is only a trace of a metastyle. M^3 is small. The anterior elements are well developed, but the hypocone and metacone are much reduced.

Inferior Dentition.—The only premolar that is preserved is just erupting and is somewhat injured.

In all the molars the anterior cusps are much higher than the posterior ones. The protoconid and metaconid are connate at the base and the paraconid appears as a small anterior median cusp. The protoconid and metaconid are of a nearly equal height. In the heel or talonid the hypoconid is somewhat larger—has a greater antero-posterior diameter than the entoconid. The hypoconulid is median and small. The other molars are formed in the same pattern, but they decrease slightly in size posteriorly.

The infraorbital foramen opens above M^1 , is narrow transversely and opens diagonally upward. It is in a longitudinal concavity which extends backward a short distance on the anterior part of the zygomatic arch. The posterior part of the foramen is only a little in advance of the anterior of the orbit. At the anterior upper margin of the orbit is a quite large protuberance.

The horizontal ramus of the mandible is narrow vertically. The angle projects downward and backward, the posterior angle being slightly hooked upward. The condyle is just above a line passing through the highest points of the molars. It is disk-shaped, the broad articular surface facing backward as much as upward. The coronoid process is broad. The tip is broken off. The anterior angle of the masseteric fossa is considerably behind the last molar and below the alveolar border. It is quite deep and

the anterior ridge prominent. On the inside of the mandible a convexity runs forward, dying out in a narrow ridge on the alveolar border under M_3 .

The great trochanter of the femur is not high. The lesser one is prominent posterior to and a little below the head. The third trochanter is small. The middle part of the shaft is nearly circular in section.

Measurements.

UPPER JAW.

	M.
Length of last two premolars and the true molars .....	.0137
Length of molar series .....	.0068
Length of P^3 .....	.0034
Width of P^3 .....	.0023
Height of crown of P^3 .....	.002
Length of P^4 .....	.0031
Width of P^4 .....	.0033
Length of M^1 .....	.003
Width of M^1 .....	.004
Length of M^2 .....	.0026
Width of M^2 .....	.004
Length of M^3 .....	.0016
Width of M^3 .....	.0031

LOWER JAW.

Length of molar series and last premolar .....	.012
Length of molar series .....	.0085
Length of P_4 .....	.0035
Length of M_1 .....	.0028
Width of M_1 .....	.0021
Height of M_1 .....	.003
Length of M_2 .....	.003
Length of M_3 .....	.0025
Width of M_3 .....	.0019
Height of M_3 .....	.0024
Depth of ramus under M_1 .....	.0051
Depth of ramus under M_3 .....	.0041
From posterior of M_3 to posterior of condyle .....	.013
Length of femur .....	.046

Steneofiber hesperus, sp. nov.

Part of the left horizontal ramus of a mandible (No. 41) containing all the teeth. The tip of the incisor is gone. The specimen was found in a light colored sandy clay near Blacktail Deer creek, about thirty miles above Dillon in Beaverhead county. It was near the top of an exposure in which, a considerable distance below, were the remains of *Arretotherium*, to be described later, and part of the skull of a quite large rhinoceros.

The mandible is somewhat smaller than that of *S. pansus* of the Loup Fork of New Mexico. It is less robust, not being so deep or thick. The masseteric area does not extend so far forward. There is some difference in the enamel pattern of the teeth, but just how much is due to wear I cannot say. That of the premolar in the present species is more complex, being crenulate or minutely folded on the inner lakes and inflections. This tooth is smaller especially at the top, but much wear would bring this surface nearer to the area of that of *S. pansus*. The two anterior molars are broader and longer. The teeth do not appear so high from the outside, but are higher above the alveolar border on the inside. The outer enamel inflections do not extend so far down on the outside of the teeth, are more open and incline more forward and the outer lobes are more angulate. There are small extra enamel islets on M_1 and M_2 . There is no sharp antero-internal angle on the premolar. These comparisons are made with No. 10575 of the Princeton collection labeled *Castor pansus*, Camp creek, Oregon, which evidently does not differ at all from Cope's type from New Mexico (1877, p. 297, Pl. LXIX, Figs. 4 and 5).

In none of the teeth are the principal inner and outer enamel inflections converted into lakes.

At its preserved stage of wear the grinding surface of P_4 has three divisions, an anterior outer, an anterior inner and a posterior. The anterior outer division is three-lobed, or is a crescent with a long limb extending inward and somewhat backward from near the posterior horn. The anterior horn is at the antero-external angle of the tooth. From this the crescent sweeps backward and inward, the outer border forming the outer margin of this part of the premolar. The inner limb extends transversely inward to the inner border. The anterior inner crescent of the tooth begins near the anterior border of the preceding one, the outer margin forming the anterior and anterior inner border of the tooth. On the posterior part of this crescent near the antero-external horn is a rounded lobe. Much wear would make the two anterior crescents confluent. The posterior part of the tooth is a transverse, pointed oval with the smaller end outward and slightly deflected forward. Its enamel lake has nearly the same form but with sinuous margin. Much wear would perhaps make the enamel pattern nearer like that of *S. pansus*.

The enamel folds and lakes are inclined to be more curved and the enamel borders more sinuous than in *S. pansus*. There is an extra islet in the two anterior molars. In M_1 it is posterior to the anterior lake and in M_2 it is anterior.

The anterior surface of the incisors is more convex than in the beaver, *Castor canadensis*, and the antero-posterior diameter is proportionally greater.

Measurements.

	M.
Length of molar-premolar series .....	.017
Length of P_4 at base .....	.005

	M.
Width of P_4 at base .....	.0045
Length of M_1 .....	.004
Width of M_1 .....	.0045
Length of M_2 .....	.004
Width of M_2 .....	.0042
Length of M_3 .....	.004
Width of M_3 .....	.0036
Depth of ramus under middle of P_4 .....	.012
Depth of ramus under posterior of M_1 .....	.011

Steneofiber complexus, sp. nov.

The type of this species is part of a skull and mandible with complete dentition (No. 42). It was found in a gray sandy layer in a ravine cutting through high bluffs of supposed White River age on the west side of the Madison river, in the Lower Madison valley, about nine or ten miles south of Three Forks. As this specimen and some limb bones of a rhinoceros-like animal are the only fossils of importance obtained here, and as the exact relations with the lower White River fossil-bearing beds northwest of Three Forks, about fourteen miles distant, have not been made out, it is impossible to say to just what horizon these beds belong.

This is a young individual. Only one premolar—the right upper one—has been shed. All of the molars are fully protruded and considerably worn. The upper permanent premolars are farther advanced than the lower, which evidently had only begun to grow.

This species seems to be nearest like Cope's *S. (Castor) peninsulatus* (1883, p. 840, Pl. LXIII, Figs. 18–21). The skull is damaged, yet some points of interest can be made out. There is a marked difference in the mandibles of the two species. In the present one the masseteric area does not extend so far forward, the anterior margin of the coronoid process rises opposite the back part of the third cheek tooth (M_2), and is nearer to the molars. This process has an entirely different form in the present species. It is high; the anterior border is straight and rises steeply. The angle is inflected inward and is rounded, not angulate anteriorly and posteriorly as in *S. viciacensis* (see Filhol, 1891, Pl. 5).

The Dentition.—The anterior face of the lower incisor is not so convex as in *S. hesperus* just described. The posterior angle is not so acute but is broadly rounded. The outer part of the cutting edge is rounded, not angulate, and the inner worn, beveled surface is long and longitudinally concave. Below this the transverse is just a trifle greater than the antero-posterior diameter.

The upper cheek teeth are very complex on account of the number and the curving of the enamel lakes and inflections and the sinuosity of the enamel. This might be simplified on further wear. The inner loops extend forward as much as outward, and some of

the lakes are nearly antero-posterior. In the lower teeth also the enamel of the lakes and inner enamel inflections is much lobed.

I will defer a detailed description of these teeth for a paper which has been partly written, describing several new species of Mylagaulidæ and throwing considerable light on their development.

Measurements.

SKULL.		M.
From anterior of incisor to posterior of M ³ .....		.0384
From posterior of incisor to anterior of P ⁴ .....		.021
Transverse diameter of incisor ..		.0032
Antero-posterior diameter of incisor .....		.0033
Length of molar-premolar series .....		.0123
Length of temporary P ⁴ .....		.0033
Width of temporary P ⁴ .....		.0038
Length of M ¹ .....		.0032
Width of M ¹ .....		.0035
Length of M ² .....		.0032
Width of M ² .....		.0034
Length of M ³ .....		.0022
Width of M ³ .....		.0032
LOWER JAW.		
Anterior tip of incisor to posterior of M ₃ .....		.033
Length of molar-premolar series .....		.0146
Length of P ₄ .....		.0038
Width of P ₄ .....		.003
Length of M ₁ .....		.003
Width of M ₁ .....		.004
Length of M ₂ .....		.0032
Width of M ₂ .....		.004
Length of M ₃ .....		.0032
Width of M ₃ .....		.0033

Palæolagus Leidy.

In the Pipestone beds quite a number of jaws and teeth of *Palæolagus* were found. They apparently belong to three species. One has the third column on the lower molars as in *P. triplex*. The three portions of mandibles preserved are somewhat smaller than the one described by Cope (1883, p. 881, Pl. LXVII, Fig. 28), and may belong to a different species.

Several upper and lower jaws I cannot distinguish from *P. turgidus*.

Palæolagus temnodon, sp. nov.

There are three series of upper teeth (Nos. 43, 44 and 45) which differ in some respects from previously described species. They vary somewhat in size. P³—the first

cheek tooth—has two anterior grooves instead of one. It lops backward, its upper posterior part resting against P^4 . On M^3 of the largest one (No. 42) there is a rudiment of a posterior lobe. From Pipestone creek.

Measurements.

	No. 43.	No. 44.
	M.	M.
Length of molar-premolar series.....	.0123	.0141
Length of molar series.....	.0051	.0061
Width of M^1.....	.0004	.0045

Cylindrodon fontis, gen. et sp. nov. (Plate IX, Figs. 9, 9a.)

Of this rodent I have two portions of right mandibular rami (Nos. 38 and 39). One has all the cheek teeth and the greater part anterior to the ascending ramus; the other has the three posterior teeth and part of the ascending ramus, but not the angle, coronoid process or condyle. They were obtained from the Pipestone beds, associated with *Palaeolagus*, *Ischyromis*, etc. The Pipestone springs, near where the fossils were found, suggested the specific name.

The diastema was short; the teeth are cylindrical with a central enamel islet and an outer enamel inflection. The lower border of the ramus is convex fore-and-aft, and is shallow but thick under M^3 . The anterior angle of the masseteric area extends forward to M^1 and is near the alveolar border. The anterior border of the ascending ramus rises opposite M^3 and leaves a broad space between the two. The surface of the masseteric area is nearly flat, with a convexity considerably behind and above its anterior angle. On the inside, back of the teeth, from the horizontal ramus a large convexity passes backward, outward and upward on the ascending ramus. Above and below this the bone is thin. The mental foramen is small and is situated above the middle of the jaw, a little in advance of P^4 .

The teeth are very characteristic, yet they are simple. As seen from above they look like a large comma, with a short tail directed outward. Their order of size, beginning with the smallest, is M^3 , P^4 , then M^1 and M^2 , which are nearly equal in size. The teeth are evidently quite long vertically, except the last which is short, as it is so nearly approached by the posterior portion of the canine. The incisors are thicker antero-posteriorly than transversely.

Measurements.

	M.
Length of molar-premolar series .....	.0076
Depth of ramus under P^4.....	.0064
Depth of ramus just back of M^3 .....	.0046
Thickness of ramus under P^4.....	.003

	M.
Thickness of ramus at $M_{\overline{5}}$ .....	.004
Length of P_4 .....	.003
Width of P_4 .....	.0021
Length of M_1 .....	.0021
Width of M_1 .....	.0022
Length of M_2 .....	.0021
Width of M_2 .....	.0022
Length of M_3 .....	.0014
Width of M_3 .....	.0015

Sciurus jeffersoni, sp. nov.

Type No. 40.

This species is larger than *S. relictus* (Cope, 1883, p. 817, Pl. LXV, Fig. 35). The teeth do not increase regularly in size backward. The mental foramen is higher and nearer to the incisor. The diastema was shorter.

In this species the anterior cheek tooth is the smallest and the posterior one the largest, but the two between are nearly equal in size. In all of the teeth the anterior inner tubercle is the higher and larger and the posterior inner one the smaller. The latter does not appear as a separate tubercle on $M_{\overline{3}}$, as a continuous wall extends from the anterior inner to the posterior outer one, enclosing the basin internally and posteriorly. A small ridge, which may represent the posterior inner tubercle, extends from the wall backward and inward in the posterior part of the basin. On the anterior three teeth there are minute tubercles between the two internal ones. There are also minute median tubercles on the outer margins of all the teeth.

From White River beds, Pipestone creek.

Measurements.

	M.
Length of lower molar-premolar series .....	.012
Length of P_4 .....	.0026
Width of P_4 .....	.0029
Width of molars, each .....	.003
Length of M_1 .....	.0029
Length of M_2 .....	.003
Length of M_3 .....	.004

Eumys minor, sp. nov.

The type of this species, No. 37, is part of a right ramus of a mandible from the Pipestone beds on Pipestone creek, in Jefferson county. The anterior part of the incisor is gone and all of the mandible back of the second molar. The two anterior molars are perfect.

This species is much smaller than *E. elegans* Leidy. The mental foramen is near the upper border of the diastema and apparently much in advance of the middle. The anterior angle of the masseteric area is under the anterior molar. Both teeth are somewhat worn on their grinding surfaces. Their antero-posterior diameters are nearly equal, but the second is broader transversely than the first. The anterior part of the first molar (cheek tooth) is not plainly divided into two lobes, but is subconical with a pit in the middle of the truncated apex. Its transverse is greater than its antero-posterior diameter. It is not much worn. It is smaller than the posterior portion of the tooth, in which there is a posterior outer tubercle, from which three slender lobes extend inward. The anterior lobe is the longest and the posterior the shortest. The second tooth has the two rounded outer tubercles and five slender inner lobes. It looks as if each outer tubercle sent in three inner lobes, but the contiguous two unite to form one median one. On looking at the grinding surface, it is not easy to make out the four principal lobes as it is in Leidy's figure of a tooth of *E. elegans* (1869, Pl. XXVI, Fig. 13). On examining the tooth from the inside it is seen that, beginning anteriorly, the second lobe forms the large anterior inner tubercle and the fourth the posterior one. The first and fifth are accessory, and the third is in the median valley between the two tubercles. It seems that a little further wear would unite the two anterior lobes.

Measurements.

	M.
Depth of jaw at mental foramen .....	.0031
Depth under second molar.....	.0039
Thickness under second molar .....	.0025
Length of first molar .....	.0015
Width of first molar.....	.0013
Length of second molar .....	.0015
Width of second molar .....	.0017

Hyænodon montanus, sp. nov.

Type No. 46.

A portion of a skull and mandible with all the teeth represented except the lower incisors. Found northeast of Toston, a village on the Missouri river, southeast of Helena. This was the only fossil secured from this stratum; but teeth of two species of *Colodon* were found in lower strata. The skulls of *Oreodon robustum*, *O. culbertsoni* (?), and *Eucrotaphus helenæ* were found farther to the northeast, but I am not sure whether the beds are higher or lower.

Larger than *H. crucians*; crown of upper canine nearly straight; crown of P² high and without posterior cusp; talons on P₃ and P₄, but not on P₂.

The canine is long and slender but not curved backward toward the apex. P_2^2 has a high crown as in *H. cruentus* and *H. horridus*. It has no heel and is therefore nearly like that of the former species. The anterior border is only slightly convex longitudinally. The posterior is concave as in that species. There is a small tritocone on P_3^3 , and the rudiment of a deuterocone supported by an inner root. In P_4^4 the tritocone, the deuterocone and its supporting root are all larger. There is no antero-external basal cusp.

The lower canine curves backward. P_1^1 is small and low, P_2^2 bends backward. It is higher than P_3^3 . P_4^4 is much larger and higher than P_3^3 .

Measurements.

UPPER JAW.		M.
Length of upper series of teeth, exclusive of incisors .....		.094
Length of upper molar-premolar series .....		.083
Length of upper premolar series .....		.053
Length of upper canine .....		.012
Width of upper canine .....		.0083
Height of crown of upper canine .....		.026
Length of P_1^1 .....		.009
Height of crown of P_1^1 .....		.007
Length of P_2^2 .....		.0125
Height of P_2^2 .....		.014
Length of P_3^3 .....		.0135
Height of P_3^3 .....		.010
Length of P_4^4 .....		.013
Height of P_4^4 .....		.011
Length of M_1^1 .....		.013
Height of M_1^1 .....		.010
Length of M_2^2 .....		.017
Height of M_2^2 .....		.011
LOWER JAW.		
Length of lower series of teeth, exclusive of incisors .....		.092
Length of lower molar-premolar series .....		.090
Length of lower premolar series .....		.052
Length of lower molar series .....		.039
Length of lower canine .....		.011
Width of lower canine .....		.0095
Length of P_1^1 .....		.008
Height of P_1^1 .....		.004
Length of P_2^2 .....		.011
Height of P_2^2 .....		.010
Length of P_3^3 .....		.0125
Height of P_3^3 .....		.011
Length of P_4^4 .....		.0133

	M.
Height of P_4 .....	.012
Length of M_1 .....	.0095
Length of M_2 .....	.0105
Height of M_2 .....	.010
Length of M_3 .....	.017
Height of skull above M^1 about .....	.062

Hyænodon minutus, sp. nov.

Type No. 47.

This consists of only a lower sectorial tooth, but it is so minute that it cannot be confused with any known species, unless it be *H. mustelinus*, which is considerably larger. It is the second molar of the right side. It shows considerable lateral wear on the outside, showing that it was not a young animal. At the top of the cusp are two beveled, worn surfaces, where the white dentine shows through the black enamel. The dentine also is exposed on the anterior surface near the root. The tooth is thick in proportion to its length. There are minute ridges on the anterior angles and a faint median convexity. There is also a minute ridge in the posterior median surface. Probably the most characteristic thing is the size.

Measurements.

	M.
Antero-posterior diameter .....	.0075
Transverse diameter .....	.0049

From Pipestone beds near Whitehall, Jefferson county, Montana.

Colodon cingulatus, sp. nov.

Type No. 62.

Part of maxillary with P^3 , P^4 , M^1 and base of P^2 .

A prominent cingulum entirely surrounds the last two premolars. The internal cusps—the deutocone and tetartocone—are just beginning to divide, as indicated by a shallow furrow on the inner side. The protostyle, protocone and tritocone are all convex on the outside. The protocone and tritocone are nearly equal in size, but the protostyle is not so large or high. The metaloph is higher than the protoloph, the latter nearly dying out before it reaches the protocone. In other words, it ascends steeply as it passes outward toward the protocone.

In M^1 the paracone, parastyle, metacone and hypocone all appear as subconical cusps. The parastyle is much smaller than the paracone, and is situated in front of it and does not send backward a prominent cingulum on the outer face of the paracone as in *C. procus-*

pidatus. The distance from the apex of the paracone to the apex of the metacone is the same distance as from the latter to the apex of the hypocone.

There are at least two infraorbital foramina. They open in a concavity in the face above the third and fourth premolars.

From Toston beds near the Missouri river, above Townsend.

Measurements.

	M.
Length of last three premolars and first molar .....	.0407
Length of P ² at base .....	.009
Width of P ² at base .....	.012
Length of P ³ .....	.0115
Width of P ³ .....	.0173
Length of P ⁴ .....	.012
Width of P ⁴ .....	.0182
Length of M ¹ .....	.0145
Height of infraorbital foramina above alveolar border.....	.018
Distance between the two infraorbital foramina exposed.....	.0065

Colodon, sp.

No. 63.

A last upper molar in a fragment of the maxillary.

This is larger than *C. dakotensis*. The tooth is considerably worn. The parastyle is as large as the paracone and is more convex on the outer surface. The metacone is small. From Toston beds.

Measurements.

	M.
Length of M ³ .....	.020
Width of M ³ .....	.022

Bathygenys, gen. nov. (Plate IX, Figs. 7 and 8.)

Type Nos. 48 and 66.

Among the remains of small animals that were found in the Pipestone beds are two portions of mandibles that are of much interest, as, disregarding size, they are so very much like the corresponding parts of some of the Loup Fork specimens from Montana that I have put in the genus *Merycochærus* (1900 and 1901). I have not made a careful study and comparison, but since seeing the fine specimens of *Merycochærus* in the American Museum of Natural History, I think it is very likely that the Montana forms above referred to should be put in a new genus, so I will at present refer these to *Merycochærus* with a question mark, as: *Merycochærus* (?) *laticeps*, *M.* (?) *altiramus*, etc.

The parts of the present specimens are small, being anterior fragments of mandibles, yet these parts are so perfectly characteristic in *Merycochærus* (?) that I cannot avoid the belief that if the skull of this animal is found it will show a strong leaning toward that genus, and I would not be surprised if it proved to be the White River ancestor. This is made more probable by the fact that none of the *Oreodontidæ* that have been described can be considered as ancestral to *Merycochærus*, either the true genus or the doubtful one. I do not refer to the John Day forms, *Promerycochæri*, which have been included in that genus. They are a very different animal.

The specimens are (48) the anterior part of a right ramus of a mandible, with part of the alveolus of the canine, the root of P_1 , the alveolus of P_2 and the last two premolars complete, and (66) a part of a right ramus with the last three premolars and the first molar.

There are four ways in which it differs from *Merycochærus* (?). It is only a fraction of the size; it has, like some species of *Leptauchenia*, two mental foramina; the premolar teeth are not crowded, and the teeth are not so high. The premolar series was probably as long as the molar series.

In the form of the chin and symphysis, the depth of the jaw, the narrowness of the space between the rami back of the symphysis, the evident reduction of the incisors, the smallness of the canine, the lenticular section of P_1 , the forms of all the teeth preserved, their narrowness in proportion to their length, are all like *Merycochærus* (?). It may be that these two fragments belong to different species, so to save confusion I will describe them separately.

Specimen 48.—The anterior upper tip of the ramus is broken off. This shows anteriorly a transversely narrow broken surface, nearly in the middle of which is the canine alveolus, but no hint of incisors. It is very doubtful if there was the full number. If there was they must have been exceedingly small or placed anteriorly to the canine. The anterior surface of the chin as far as shown is steep and straight along the symphyseal suture. It is convex transversely. The anterior mental foramen is beneath the posterior part of P_3 , the posterior one a little behind the middle of P_4 . They are a little above the longitudinal middle line of the ramus. The anterior is the larger. The symphyseal suture is broadest below and narrows upward as in *Merycochærus* (?). The posterior of the symphysis is under the anterior part of P_4 .

The canine was evidently much smaller than P_1 . P_1 is lenticular in section with nearly equal sides and rounded angles, the longest diameter being obliquely fore-and-aft, and directed posteriorly outward and anteriorly inward as in *Merycochærus* (?). P_2 had two roots near together. P_3 has a proportionally large, paraconid, which as the tooth is viewed from the outside is seen to be separated above by a distinct notch from the pro-

toconid. The deuteroconid is only represented by a narrow ridge passing part way down the tooth inward and backward from the apex of the protoconid. The metaconid is much better developed and is represented by a posterior tubercle, connected by a narrow ridge with the apex of the protoconid.

In $P_{\frac{1}{4}}$ the paraconid is thicker and higher than in $P_{\frac{3}{8}}$, and is inflected inward. The other four elements—the protoconid, metaconid, deuteroconid and tetartoconid*—are all well developed and surround a quadrangular cup-shaped depression. This is true also of *Oreodon* and *Eucrotaphus*, and the form of the tooth differs very little from these. In this particular tooth, however, the posterior depression would, on further wear, make an islet, not an enamel loop. It is shallow and would entirely disappear if there should be much wear. The great difference between this tooth and the corresponding ones of the above-named genera is in the narrowness of the tooth as compared with its length. $P_{\frac{3}{8}}$ also differs in this respect and they are, therefore, more like *Merycochærus*(?). $P_{\frac{3}{8}}$ differs from that of *Oreodon culbertsoni* in the simplicity of the inner ridges—rudimentary deuteroconid—in this respect being much like the specimen I have examined of *O. gracilis*. It also differs in having the paraconid partly separated from the protoconid. Again in these slight variations the differences are in the direction of *Merycochærus*(?). In the type of *M.*(?) *altiramus*, which I have described from the Loup Fork of Montana, the teeth are little worn and give an excellent opportunity for comparison (1901, p. 73, Fig. 1). The present species shows almost no advance on this pattern. The paraconid on the last two premolars is a little thicker, and this element is distinguishable on $P_{\frac{1}{2}}$, which has just begun to develop the posterior elements. The teeth have all increased in height.

Specimen No. 66.—In this specimen the mental foramina are farther apart. The anterior one is under the anterior part of $P_{\frac{3}{8}}$ and the posterior one under the anterior of $P_{\frac{1}{4}}$. There is a thickening of the ramus—an outer convexity between these two foramina—not seen in No. 48.

$P_{\frac{1}{2}}$ is shorter than $P_{\frac{3}{8}}$ and the roots are not close together as in the other specimen. $P_{\frac{3}{8}}$ is about the same. $P_{\frac{1}{4}}$ has the metaconid and tetartoconid much lower and they are not united at the posterior inner angle of the tooth, so that after considerable wear there would still be an opening to the inner basin as in *Oreodon* and *Merycochærus*(?). $P_{\frac{3}{8}}$ and $P_{\frac{1}{4}}$ are broader than in No. 48.

$M_{\frac{1}{2}}$ is shorter than $P_{\frac{1}{4}}$. The posterior pair of crescents is wider than the anterior pair. The outer crescents are short antero-posteriorly.

I will propose for the specific name *P. alpha*, with No. 48 as the type specimen.

* The tetartoconid is small.

Measurements.

SPECIMEN 48.

	M.
Depth of jaw at angle of chin .....	.0155
Greatest width of symphyseal suture .....	.0083
Distance between mental foramina.....	.004
Thickness of ramus behind symphysis.....	.006
Length of premolar series.....	.0175
Length of P ₁.....	.0042
Width of P ₁.....	.0027
Length of P ₂.....	.005
Width of P ₂.....	.0022
Height of crown of P ₂.....	.0026
Length of P ₃.....	.0052
Width of P ₃.....	.0031
Height of P ₃.....	.0027

SPECIMEN 66.

Distance between mental foramina .....	.005
Length of last three premolars .....	.014
Length of P ₂.....	.0042
Width of P ₂.....	.002
Length of P ₃.....	.005
Width of P ₃.....	.0029
Length of P ₄.....	.005
Width of P ₄.....	.0037
Length of M ₁.....	.005
Width of M ₁ anterior.....	.0036
Width of M ₁ posterior .....	.0042
Height of crown of M ₁ .....	.0024

Limnenetes, gen. nov.

The skull (No. 49) which I take as the type of this genus was found on a side hill about three miles northwest of Three Forks. It was near vertebræ of a small *Titanotherium*. The skull most nearly resembles *Orcodon gracilis* in size, yet it differs more or less from that species in most respects. The most striking characteristics are the following:

Skull low; frontal plane nearly flat; orbits open behind and as high as possible without arching of the frontal plane; a separate interparietal; tympanic bullæ large and longitudinally elliptical; basioccipital sharply angulate; zygomatic arches nearly parallel; sagittal crest low.

This skull belonged to an old animal and the teeth are so worn that their structure cannot be made out. There are other skull fragments with good teeth which were found in the same beds a couple of miles away. There are some differences, but I provisionally refer them to the same genus and describe part of them under the name of *P. anceps*.

Limnenetes platyceps, sp. nov. (Plate IX, Figs. 5 and 6.)

No. 49.

This is the skull on which the genus *Limnenetes* is founded.

Though the teeth are much worn it can be seen that the last two premolars are small. P^3 is triangular, and P^4 very short antero-posteriorly. The skull expands rapidly just anterior to the orbits and continues nearly the same width to the post-glenoid processes, giving this portion a rectangular aspect as seen from above. The anterior part of the nose is gone, so that only the posterior parts of the nasals are preserved.

The naso-frontal suture is short. From the naso-maxillary suture it extends backward and slightly inward, then nearly transversely to the median line, not forming a wedge. The nasals are narrow—not so wide as in *Oreodon gracilis*. They are flat on top as far as seen. The anterior lachrymal suture is nearly a semicircle. The lachrymal pit is shallow, and, with the orbital border just behind, is rugose. The supraorbital foramina are small and open a little less than one-third the distance from the frontal suture to the supraorbital border. The channels from these sweep forward and slightly inward, then outward and downward over the face, then backward to the infraorbital foramina which open above P^4 .

The frontals, though nearly flat, are slightly concave between the orbits with a low convexity along the frontal suture. Between the channels from the supraorbital foramina the surface is flat, but outside these convex.

The orbits are much larger than in *Oreodon gracilis*. They are circular and their upper borders lack only the thickness of the frontals above of being as high as the frontal plane—in fact they are about on a level with the slightly depressed median part of the frontal region. There are postorbital processes to the frontals and jugals, but they do not nearly meet, but end in points about 5 mm. apart.

The temporal ridges, beginning on the postorbital processes of the frontals, converge rapidly, then with a gentle backward curve meet about in the plane of the anterior borders of the glenoid surfaces. The parieto-temporal sutures follow these ridges for a little distance, then converging more rapidly form a wider angle in front of the stephanion. The sagittal crest is low, being highest just back of where the temporal ridges unite. Back of this it descends and becomes very low in front of the inion. A narrow median groove can be seen nearly the whole length. The inion is low—a little three-cornered area much lower than the frontal plane. Measuring from a line in the plane of the palate, it does not extend farther posteriorly than the occipital just above the foramen magnum.

The brain-case is full and well rounded out. It is broadest midway between the

middle transverse plane of the orbits, and theinion. Inward and backward from this are two convexities, one on each side of the higher part of the sagittal crest. The parieto-temporal suture makes a sigmoid curve upward and backward over the greater convexity of the brain-case and then extends backward parallel with the sagittal crest.

The interparietal is perfectly distinct from the other bones, having a well-defined suture all around. It is an equilateral triangle. The anterior angle is wedged in between the narrow, forked posterior processes of the parietals. It does not extend quite back to the posterior part of the skull, a narrow border of the supraoccipital intervening. The lambdoid ridges are low, not extending into wings.

The supraoccipital is nearly as broad as high. It is more nearly flat than in *Oreodon culbertsoni* or *O. gracilis*. Above it is slightly concave, with a hint of a median ridge. Below it is broadly convex and almost flat above the foramen magnum.

The basioccipital is narrow and sharply angulate below, the angular portion being in the same plane as the palate.

The tympanic bullæ are near together, large, high, evenly rounded, elliptical in outline, as seen from below, with the longer axis antero-posterior; and they project downward farther than any other elements of the skull.* They are proportionally larger than in *Eporeodon* (Princeton Col., No. 10586). The external auditory meatus is trumpet-shaped like that of *Oreodon culbertsoni*, and it fills the space between the exoccipital and the post-glenoid process. The foramen ovale is above the anterior portion of the tympanic bulla. The foramen rotundum is small and just outside the posterior beginning of the pterygoids.

The posterior nares open between the anterior lobes of the last molars. The posterior median portions of the palatines end in a blunt point. The palate is concave in a transverse line and narrow. The posterior palatine foramina are between the interval between the last premolars and first molars.

The glenoid surface is somewhat convex antero-posteriorly, about the same as in *Oreodon culbertsoni*. The post-glenoid processes are broad transversely, bounding the whole glenoid surface posteriorly and extending outward nearly as far as the maximum expansion of the zygomatic arches, which is just anterior to the glenoid surface.

As before stated, the skull is very nearly the size of that of *Oreodon gracilis*. Its likeness to that seems more apparent on hasty examination than after detailed study. In many respects, as in the flatness of the top of the skull, the large size and superior position of the orbits, the shape of the brain-case and the size and form of the tympanic bullæ, it more resembles *Eporeodon* (?). In a specimen of this genus (Princeton Coll., No. 10568) which I have used for comparison, the postorbital processes of the frontal and

* Probably the paroccipital processes extended lower, but they are broken off.

jugal are but barely united, so that the present specimen comes nearer to *Eporeodon* (?) in this respect.

The beds from which this fossil was obtained are undoubtedly older than the *Oreodon* beds of South Dakota and very likely correspond to the lower *Titanotherium* beds; yet it is very doubtful whether this form is directly ancestral to *Oreodon culbertsoni* or *O. gracilis*, though I should say that it is more closely related to the latter. It is more probable that it is ancestral to *Eporeodon*, and that at least the forms with excessively large bullæ form a separate line from the *Unita*. But it is difficult to make comparisons or draw conclusions on account of the chaotic condition of this family. It probably will remain so until some one who can do it properly can have the opportunity of studying the vast amount of material that has been collected and who will undertake the enormous task of "straightening things out." There are about twenty species belonging to this family that have been found only in Montana.

Measurements.

	M.
Length of skull from anterior of P ³ to posterior of occipital condyle .....	.085
Length from back of M ³ to back of same.....	.049
Width of skull at fourth premolars. ....	.030
Width of skull at third molars .....	.062
Width of skull just anterior to glenoid surfaces .....	.065
Height of skull at fourth premolars .....	.025
Height of skull at centre of orbits .....	.030
Height of skull at occiput .....	.033
Width of skull between middle of orbits.....	.037
Width of brain-case.....	.0895
Diameter of orbits, antero-posterior.....	.020
Diameter of orbits, vertical .....	.020
Length of P ³ .....	.0055
Width of P ³ .....	.0055
Length of P ⁴ .....	.005
Width of P ⁴ .....	.0077
Length of M ¹ .....	.008
Width of M ¹ .....	.010
Length of M ² .....	.010
Width of M ² .....	.011
Length of M ³ .....	.011
Width of M ³ .....	.012

Limnenetes (?) *anceps*, sp. nov.

About two miles from where I found the type skull of *L. platyceps* I found several fragments of skulls and mandibles of *Oreodontidæ*. They were found in the same spot, but belong to at least five different individuals. One was a small *Agriochaerus*, *A. minimus*, which will be described in this paper. In the same place were toe bones and part

of the femur of a rhinoceros, probably a small *Cænopus*. A little distance away were remains of a *Titanotherium*. A mile or two farther north were quite a number of *Titanotherium* bones and there I obtained large portions of two skeletons.

The specimen which I take as the type of this species is the greater part of the anterior portion of a cranium (No. 50). Part of the snout and right maxillary are gone, but the root of the canine on the right side and the last two premolars and all the molars on the left side are preserved. It is only a little smaller than *Oreodon gracilis*.

Compared with *L. platyceps*, the frontal plane is still more flat but narrower; the lachrymal depressions are larger, deeper and different in shape; the infraorbital foramen is farther forward, being above P^3 instead of P^4 ; the nasals are different in shape and extend farther back.

The nasals are narrow, but broadest between the slender tips of the frontals. From here they narrow anteriorly to where they are broken off, and posteriorly to where they end in two small tips separated by a small wedge of the frontals. The latter, of course, may be only an individual character. This posterior extension of the nasals with the narrowness of the top of the skull make the anterior projections of the frontals rather long and narrow, and they end in slender tips which are wedged in between the nasals and the maxillaries. The lachrymals are larger than in *L. platyceps*, are not so nearly semi-circular and they send up a peninsula of bone toward the nasals. The lachrymal depressions are deep and longitudinally elliptical. The teeth are so much like those of *Oreodon gracilis* as not to need a separate description. Compared with the specimen (Princeton Col., No. 11396) which I have used for comparison, P^2 is a little more triangular and the median and anterior outer horns of the crescents are less prominent. One of the supraorbital foramina is farther back than the other, and shallow channels can be traced to the infraorbital foramina as in *L. platyceps*.

Among the other fragments is part of a skull (No. 52) that appears to be different from either of the preceding, but it belongs to a young animal. A small part of the post-orbital process of the frontal is gone, but it was undoubtedly short and the orbit open behind.

There is also a series of milk teeth (No. 51), but not enough of the skull to determine the species.

Measurements of type specimen.

	M.
Length of dental series, exclusive of incisors	054
Length of molar series.....	.028
Length of canine.....	.005
Width of canine.....	.045
Length of P^3.....	.006
Width of P^3.....	.0065

	M.
Length of P ⁴.....	.006
Width of P ⁴.....	.008
Length of M ¹.....	.008
Width of M ¹.....	.010
Length of M ².....	.010
Width of M ².....	.012
Length of M ³.....	.0095
Width of M ³.....	.0125
Width of nasals, greatest.....	.0112
Width of skull between anterior of orbits.....	.030
Diameter of lachrymal depressions, antero-posterior.....	.013

Oreodon robustum, sp. nov.

Type No. 56.

The greater part of a skull found in bed of soft sandy clay, northeast of Toston, near the Missouri river, southeast of Helena.

It is readily distinguished from other species by several characters.

Distinguishing characters: *Size large; face and anterior nares deep vertically; nasals broad; zygomatic arch broad below orbits; palate broad; foramen ovale extremely large; tympanic bullæ very small and separated from basioccipital by a wide space; incisive foramina broad oval.*

The canines agree with the general robustness of the skull in being large. The crowns are not preserved. P¹ is narrow. P² is a little different from that of *O. culbertsoni*. It is narrower. The anterior festoons are smaller, there being two little pits, but the ridge or partition that divides them does not continue downward on the tooth. On account of the thinness of the principal cusp the posterior internal festoon encloses a larger area.

On the premaxillaries, beside the narial openings, are quite large depressions, which in their centres expose a small surface of the anterior roots of the canines. It looks as though the premaxillaries had begun to coössify. The height of the anterior nares and of the face are very marked. The nasals are broadest above the anterior parts of the lachrymal depressions. From here they are narrowed backward very regularly, ending in points. Their posterior portions form a convexity. The supraorbital foramina are farther apart than in *O. culbertsoni*.

The roof of the brain-case is broken away, showing part of the cast of the cerebrum and cerebellum.

The tympanic bullæ are similar to those of *O. culbertsoni* in form. The posterior portion, which abuts against the paroccipital, forms a process which extends downward a short distance in close contact with this larger process. Another process extends down-

ward opposite the post-glenoid. It is thin and antero-posteriorly compressed. A hint of it is seen in *O. culbertsoni* (Princeton Col., No. 10062). Another process extends backward and outward near the postero-interior face of the post-glenoid. A much larger space is left between the tympanic and the basioccipital than in *O. culbertsoni*. The ridge or convexity that bounds the inner side of the glenoid surface is much more prominent than in that species. The basioccipital is broader.

Measurements.

	M.
Length of skull from front of canine to back of paroccipital process.....	.192
Height of skull above P ¹.....	.060
Height of skull above M ¹.....	.064
Width of skull at canines.....	.055
Width of skull at anterior of orbits.....	.104
Height of narial opening over P ¹.....	.040
Width of narial opening over P ¹.....	.030
Width of molar under middle of orbit.....	.022
Width of palate between canines.....	.039
Width of palate between second premolars.....	.040
Width of palate between last molars.....	.037
Width of incisive foramina.....	.0095
Length of incisive foramina.....	.012
Length of foramen ovale.....	.009
Width of foramen ovale.....	.005
Length of molar-premolar series.....	.090
Length of premolar series.....	.045
Length of molar series.....	.045
Width of P ¹.....	.006
Width of P ².....	.0085
Width of both nasals, greatest.....	.030

Eucrotaphus helenæ, sp. nov.

Type No. 57.

The skull with the lower jaw. The anterior part of the skull and mandible, the occipital crest and zygomatic arches are gone. It was found northeast of Toston, in a bed of clay which contained nodular layers.

It was a young individual but nearly full grown, judging by the sutures of the skull. It has its temporary premolars. All the molars are fully erupted, but the last molars are unworn.

The nasals are quite broad above the third premolars. They narrow gradually and uniformly backward, ending in points in a plane with the anterior of the orbits. They are convex. The lachrymal pits are nearly circular and quite deep. The anterior prolongations of the frontals terminate in a plane with the fourth premolars. The lachrymal

is very large. The supraorbital foramina are farther apart than in *Oreodon culbertsoni*. The orbit is circular. The forehead is convex between the orbits, but concave in front of the stephanion. The brain-case is broad, full, and well rounded out. There are no distinct ridges near the parieto-temporal sutures. The anterior part of the sagittal crest is low. The brain-case here is full and arched upward. Back of this the crest is broken away, but evidently it was not high and narrow, as in *Oreodon culbertsoni* or the so-called *Eporeodon* of the White River or John Day. It appears to have been more like that of *O. gracilis*. The foramen magnum is large. The basioccipital in front of the condyles is broadly convex, then for a short space forms a rounded (not a sharp) angle, then is broadly convex again between the tympanic bullæ. The bullæ are large, but not so large as in *Eporeodon* (?) *major*. They are quite evenly rounded and longer antero-posteriorly than transversely. Posteriorly they abut against the paroccipital processes, which extend backward and outward. These processes are convex postero-internally and deeply concave antero-externally toward the bases. The post-glenoid processes are moderately thick. The posterior nares open between the posterior parts of the last molars.

The horizontal rami of the mandible are widely separated just behind the symphysis as in *Eporeodon*, but the caniniform premolars are very much nearer together and are nearly circular in section. The angle descends below the horizontal ramus. The coronoid process is narrow at its base and the condyle is a short distance behind it, making the sigmoid notch and the upper part of the mandible narrow antero-posteriorly as compared with *Eporeodon* (Princeton Col., 10586). The upper molars have very prominent outer horns to the crescents.

This animal resembles both *Oreodon gracilis* and *Eporeodon*, which perhaps form a different line from that of *O. culbertsoni*, but the latter is so variable and the validity of *Eporeodon* is so doubtful that I will not attempt the task of making comparisons. Even if *Eporeodon* is a valid genus this animal is quite different, and I prefer to use the older name *Eucrotaphus*.

Found in Toston beds in Broadwater county.

Measurements.

	M.
Length of skull from anterior of P ₂ to posterior of occipital condyles .....	.158
Length from back of last molar to back of condyles .....	.080
Width of skull at middle of orbits.....	.104
Width of postorbital constriction .....	.035
Width of brain-case, greatest.....	.055
Width of condyles.....	.038
Width of foramen magnum .....	.021
Width of palate at last molars.....	.040
Length of paroccipital processes.....	.027

	M.
Length of bullæ, antero-posterior .....	.021
Width of bullæ .....	.016
Length of last three temporary premolars .....	.033
Length of molar series .....	.047

Agriochærus maximus, sp. nov. (Plate IX, Fig. 4.)

Type No. 58.

Of this animal there is a right molar-premolar series and the last two premolars and the first two molars of the left side, with some small skull fragments. They were found on the Little Pipestone, southwestward from Whitehall. These teeth do not look like those of *Agriochærus*, principally on account of their lowness and plain, flat appearance; yet when they are compared one by one with those of *Agriochærus*, one does not feel warranted in establishing a new genus on these alone; though if a skull and skeleton were found, I have little doubt that the animal might prove to be a different thing.

Distinguishing characters: *Size large; teeth plain; the cheek teeth low, except P^1 , made up of crescents which are approximately low three-sided pyramids with broad bases.*

P^1 subconical, longer than wide, with an anterior angle and a posterior depression; two-rooted. P^2 simple, pyramidal; the outer side convex; the antero-inner nearly flat; postero-inner side concave, with a weak cingulum. P^3 three-rooted, with a small deutocone. The two inner sides equal. There is an incipient tendency toward the division of the outer crescent, as seen in the slight inner groove just behind the inner angle and the apex of the protocone. P^4 has the same length as P^2 and P^3 but is broader. The two outer crescents are not separated down as far as in the molars. The deutocone is as large, though not as high, as the outer crescents. It is subconical or subtriangular in section. There is a trace of a tritocone which looks like a cingulum. There is a faint cingulum nearer to the root.

M^1 has short, broad, low crescents, with broad open valleys between. M^2 and M^3 are the same but longer antero-posteriorly. The animal was not old, as M^3 had been recently erupted.

A small portion of the top of the skull shows the angle where the temporal ridges unite to form the sagittal crest. In the angle is a broad concavity and the ridges are broad and prominent. There is no deep groove at the angle. The anterior part of the sagittal crest is a low, broad convex ridge.

Measurements.

	M.
Length of molar-premolar series about* .....	.124
Length of premolar series .....	.052

* The posterior half of M^3 is injured, and it is reckoned as the same length as the anterior part.

	M.
Length of molar series about*.....	.070
Length of P ¹.....	.0105
Width of P ¹.....	.006
Height of crown of P ¹.....	.009
Length of P ².....	.015
Width of P ².....	.0103
Height of crown of P ².....	.0095
Length of P ³.....	.015
Width of P ³.....	.014
Height of P ³.....	.0105
Length of P ⁴.....	.015
Width of P ⁴.....	.017
Length of M ¹.....	.019
Width of M ¹.....	.022
Length of M ².....	.0245
Width of M ².....	.027
Height of M ².....	.008
Width of M ³.....	.030

Agriochærus minimus, sp. nov.

Type No. 59.

As *A. maximus* is the largest known *Agriochærus*, if it is an *Agriochærus* at all, so this species is the smallest. It is represented by the molars, last two premolars, and the zygomatic arch of the right side belonging to a mature individual. It was found in the White River beds, northwest of Three Forks, with *Limnenetes anceps*.

Specific characters: *Size small; P³ long antero-posteriorly; outer crescents of molars very low, their outer faces looking downward much more than outward.*

P³ as seen from above is nearly a right-angled triangle, with the right angle placed postero-externally. The outer surface of the protocone is concave with a faint ridge in the median line of the tooth. The tritocone is distinguished from the protocone as viewed from the inside, though it is not so apparent from the outside; but the protocone is the larger, the groove being behind the apex. The deuterocone is well developed and is opposite the tritocone. A ridge extends from its apex and along the inner side of the protocone to the anterior angle of the tooth. There are traces of a cingulum in the anterior and posterior faces of the deuterocone, and at the posterior outer base a small hint of a tetartocone.

P⁴ is nearly an equilateral triangle in cross section with a rounded interior angle, as the deuterocone is conical. The separation of the protocone and tritocone has progressed farther than in P³; the two are more nearly equal. This is apparent from

*The posterior half of M³ is injured, and it is reckoned as the same length as the anterior part.

the outside in the truncation of the apex of the tooth. A protoloph begins at the apex of the deutercone, and, becoming narrower and lower, extends to the outer anterior buttress. The tetartocone is small but well defined. A cingulum surrounds the inner part of the tooth.

The molars are broader than long. They bear very low crescents. The antero-external buttresses are large, especially on M^3 . There are inner cingula on M^2 and M^3 and faint traces on M^1 .

The zygomatic arch is quite broad under the orbit; its lower angle being opposite the posterior part of M^2 . The anterior inferior root expands outward abruptly. One root of M^3 projects through the maxillary into the orbital plane. Evidently the posterior of the orbit was in the same plane as the posterior of the last molar.

Measurements.

	M.
Length of last two premolars and molars.....	.0400
Length of molar series .....	.0250
Length of P^3 .....	.0075
Width of P^3 .....	.0062
Height of crown of P^3 .....	.0047
Length of P^4 .....	.007
Width of P^4 .....	.0084
Height of P^4 .....	.0042
Length of M^1 .....	.0085
Width of M^1 .....	.009
Length of M^2 .....	.0088
Width of M^2 .....	.0105
Height of M^2 and M^3 , each .....	.003
Length of M^3 .....	.0103
Width of M^3 .....	.012
Greatest width of zygomatic arch under orbit.....	.013

Arretotherium acridens, gen. et sp. nov. (Plate IX, Figs. 1-3.)

Type No. 60.

Of this unique animal I have most of the superior dentition and parts of the skull and skeleton. It was found in a fine sandy clay near Blacktail Deer creek, twenty-five miles south and east of Dillon, in the southwestern part of the State. Part of the posterior portion of a skull of a rhinoceros—probably *Cænopus*—about the size of *C. tridactylum*, was found in a sandy layer near, and a considerable distance above the type of *Steneofiber hesperus* was obtained. The bones are much broken and part of them had been washed out and mixed in confusion in the clay. I saved all the fragments I could find, taking some of the material to the creek and “panning it out.”

Part of the humerus of a cat, besides fragments of bones of one or two other animals, are mixed with those of this specimen, so it is sometimes difficult to be sure just what ones belong with it.

The teeth are different from those of any known animal. Those of *Hyopotamus* resemble them, especially the molars; but those of the present genus have no anterior intermediate "fifth" or "unpaired lobe," the protoconule. In this respect they are like *Merycopotamus*.

With the material in hand the principal characters seem to be the following:

All the upper teeth with sharp cusps or crescents; first premolar small; premolars increasing rapidly in size posteriorly, and composed of a simple compressed cone and a cingulum or cingulum-like cusp, which also increases in size backward; molars high, square in section, their length and breadth being nearly equal; occiput low; tarsus in the main resembling that of Oreodon.

DENTITION.

The only incisor preserved resembles the third of *Hyopotamus*, but it is much smaller and proportionally much thinner. The outside of the crown is uniformly convex. The inner side has a low, broad median convexity, so that, though thin, the tooth is thickest a little behind the middle and the edges are very thin. The anterior edge projects a little beyond the root.

Parts of two canines were found, the upper part of one and the lower part of the other. They were supposed to belong with the other teeth, as they were found closely associated with them. They are thin and sharp for an artiodactyl, yet not altogether exceptional, and they are quite sharp and finely serrate on the posterior edge. These characters, and the fact that part of a humerus of a cat was found with the other bones, makes it doubtful to what animal these canines belong. But when one sees the compressed character of the incisor and premolars and the sharpness of the apices of the molar crescents, it does not seem improbable that the canines belong to the present animal. The teeth are not more compressed than in *Moschus*, and not so long as in that genus or *Cervulus*. The serrated edge is not entirely exceptional, as Marsh has observed it in *Elomeryx armatus* (1894, p. 178, Fig. 3). The form of the tooth is not very closely like that of any cat I have seen. The whole length of the anterior edge of the crown is worn by contact with the lower canine. This, I think, does not occur in any of the cat tribe, as, at most, on account of the inner position of the lower canines and their obliqueness, only the base of the anterior part of the corresponding upper tooth could be worn by contact. The relative position of these teeth was evidently similar to that in the Peccary.

The canine is narrow laterally, more nearly flat on the inner surface and divided into three convexities by two faint longitudinal furrows. The outer surface is more convex, divided in the same way, but the middle convexity is much greater. The tooth contracts uniformly anteriorly, exteriorly and posteriorly from the base upward, ending in a small, smooth, rounded point. The appearance of the enamel is like that on the rest of the teeth, in all of which the inner angles and sometimes the outer are smooth, the other inner surfaces less so; while on the outer surfaces the enamel is slightly crinkled. The height of the crown was about .035 m.

The first premolar is small, longer antero-posteriorly than the incisor, and is thin—the thickest part and the apex being slightly anterior to the middle. The forward slope of the edge from the apex is straight, but back of the apex it drops abruptly, then slopes backward and curves downward. The thin anterior part, as in the incisor, projects a little anteriorly to the root. There is a short cingulum on the posterior inner side, which continues as a faint ridge to the anterior edge of the tooth.

Premolar 2 is longer antero-posteriorly and much higher, having a high, narrow apex, which is nearly central. From this apex the edges descend, vertically anteriorly and nearly so posteriorly for a short distance, and then both slope away, though not with exact symmetry, to the anterior and posterior edges of the tooth at the base of the crown. The outer convexity is not straight vertically. Beginning at the apex it extends downward a short distance, and then curves forward. The inner convexity is straight and median. There is an outer cingulum. The inner cingulum begins at the anterior angle of the tooth, but the posterior part is broken away.

The third premolar is nearly an enlarged copy of P². It is larger in every way. The main cusp is rather narrow, but the enlargement and expansion of the cingulum on the posterior inner part of the tooth gives the base a triangular form, with the posterior inner angle rounded. The cingulum encloses a large concavity or an oblong cup-like depression. A second premolar of a young *Hyopotamus* in the Princeton Collection (No. 10652) resembles this tooth.

P⁴ has an outer and an inner crescent, the outer being the larger, longer and higher. There is an anterior and a posterior outer buttress at the outer angles. Both the anterior and posterior cingula are large and enclose furrows between them and the crescents. The outer crescent is concave externally with a median convexity. This is also true of the inner crescent. The posterior faces of the crescents are in the same plane. The anterior horn of the internal crescent is convex on the anterior face, and abuts against a small but comparatively high conical cusp or style which partly interrupts the valley between the two crescents.

As before stated, the molars have four crescents with no fifth lobe, and the length and width are nearly equal. As nearly as I can judge from the illustrations of Falconer and Cantley (1847, Part VII, Pl. LXII, Figs. 15 and 17), the last two molars are considerably like those of *Merycopotamus dissimilis*, but here the close similarity apparently ends.

Molar 1 is so much worn that little can be said of it, except that it is much smaller than M^2 and is square in section. The anterior and posterior worn surfaces are confluent medially, and only the last narrow traces of the transverse valley are preserved, one as an external, the other as an internal projection, not quite meeting on the middle transverse line.

In the third and fourth molars the inner crescents embrace the inner bases of the external crescents, so that the median transverse valleys are much deeper than the median longitudinal ones. There are buttresses on the external horns of the external crescents; but the two median ones do not conjoin, forming a large one which cuts off the external entrance to the median transverse valley as in *Hyopotamus*. Owing to this and to the depth of the median valleys, the anterior and posterior halves of the teeth seem much more separated from each other than in that genus; in fact the last molar, especially, is almost cut in two. From the inner faces of the anterior inner crescents a short but thick cingulum extends backward and slightly outward, abutting against the anterior face of the posterior inner crescent. The anterior and posterior cingula are strong, and the depressions or valleys which they enclose are divided by the horns of the inner crescents. In the last molar the anterior horn of the posterior inner crescent continues to the anterior outer crescent, thus dividing the bottom of the transverse valley by a thin partition. The anterior roots of M^2 are connate, thus forming one broad root. This probably is true of others, but they are not enough exposed to make it certain.

Three molars on one side and the last two on the other have part of the jaws attached. The incisor, canines and premolars were found separate. There are many fragments of molar teeth of the same kind, so there must have been more than one individual.

A fragment of a mandible is present which has one imperfect tooth. It is doubtful if this belongs to the same animal as the upper teeth. It looks more like the tooth of some member of the *Pecora* than we would expect to see in this animal. It is prismatic and quite high. In section each half of the tooth is a three-sided prism, the outer crescents being V-shaped at the top, but the outer angle becomes rounded below. On one of the outer crescents or plates there is a ridge that is not exactly median, as it begins below at the base of the posterior buttress, passes diagonally upward and forward, terminating in front of the apex of the crescent. This is probably M_2 .

The Skull.—A portion of the base of the skull is preserved, including part of the occiput, the occipital condyles, the basioccipital, the exoccipitals and small portions of the squamosals.

The occiput was low as in *Hyopotamus*, which it much resembles in some respects. The occipital condyles and foramen magnum are large. Their lower articulating surfaces are nearly flat medially. They form only a slight angle with the part of the basioccipital anterior to them. Between the paroccipital processes the basioccipital is broad and moderately convex. Anterior to this it is broad and quite thin. There is a longitudinal groove on the under side on the median line on the portion between the tympanics.

The exoccipitals are similar to those of *Hyopotamus*. They are broad and thin above, convex transversely and concave vertically. They are peculiarly roughened, appearing as if they were made up of several coössified bony plates. The paroccipital processes are both broken off, but they are nearly equilateral triangles in section, nearly on a level with the inferior surfaces of the occipital condyles. They are directed slightly backward as in *Hyopotamus*. The exoccipitals are transversely convex posteriorly and concave—except at the top—anteriorly, but they send forward a high ridge or wing which rests against the tympanic internally. This latter bone is tightly wedged in between this process, the outer part of the basioccipital and the squamosal.

The external auditory meatus is small and extends inward horizontally just beneath the lambdoid crest. Aside from this the space between the exoccipital and squamosal is entirely filled with bone. The two processes, the paroccipital and post-glenoid, do not approach each other as in the American species of *Hyopotamus*. Apparently the arrangement here is more like that in the fragment of skull figured in Kowalevsky's paper on *Hyopotamus*, in Pl. XXXIX, Fig. 5 (1873). The tympanic fills the greater part of the space above referred to. There is a groove extending downward and forward which appears to be a line of bony union, so that the portion anterior to this line may be a triangular exposure of the periotic. The bullæ are not preserved, but portions of the petrous were found which show that this bone was very large. One fragment shows a cast of the cochlea. The first whorl is much larger and is broader than either of the others, which are almost equal in size of whorl, but the third is slightly thicker. The first whorl is .005 m. in diameter and its greatest thickness .0015 m.; third whorl .003 m. in diameter.

The Atlas and Axis.—Only parts of these two vertebræ are preserved. The atlas has an extremely large neural canal, but a considerable portion was occupied by the large, broad and thick odontoid process of the axis. The floor of the canal is convex fore-and-aft, with a median transverse ridge bounding anteriorly the articular surface for the odontoid process. The anterior cotyles, if not confluent below, are almost so and are not separated

by a groove. The lower surface of the atlas is nearly flat with a median anterior convexity, evidently terminated by a short spine or protuberance which has been broken off. The posterior cotyles for the axis are nearly flat, and, like the anterior ones, are almost confluent below.

The odontoid of the axis is broad and thick. As stated by Scott in the case of *Hyopotamus brachyrhynchus* (1895, p. 470), it is "neither conical nor spout-shaped, but intermediate between the two." It is broad and thick. A section at the base, also the anterior edge, are almost semicircles, so the process is approximately the sector of a sphere. The upper surface, however, is not flat, but somewhat irregular. Anteriorly it is beginning to be spout-shaped, but there is a broad median convexity. Farther back at the base is a greater prominence, terminating anteriorly in two V-shaped convexities, one on each side of the median line. With the exception of this prominence and its greater width, this process resembles that of *Agriochaerus*. The atlanteal surfaces of the axis are convex ventro-dorsally, and they slope backward more than in the last-named genus.

The Humerus.—The head is unusually flat on the articular surface, the convexity being mostly on the inner portion. The lower portion differs both from the one described by Scott as *Ancodus brachyrhynchus* and the one figured by Kowalevsky as *Diplopus* (1873, Pl. XXXVI, Fig. 4). The inner epicondyle is very uneven on the outer surface, being covered with irregular ridges and depressions. It is much thinner than in *Hyopotamus* and different in shape. Instead of being broad posteriorly to its lower extremity it has a narrow border. The trochlea is also different. The median ridge is almost as prominent as the inner one. The outer convexity is small and looks like an accessory ridge on the median one. The inner groove is deep and the ridges are not oblique.

The Tibia.—The distal end is compressed antero-posteriorly, its transverse being nearly twice its other diameter. The facets for the astragalus are very oblique, the inner one being narrower and deeper than the outer. The outer edge of the tibia is angulate to near the astragular facet, where there is a small oblique truncation. This evidently was not for the shaft of the fibula, as that lay in the broad convexity anterior and internal to the outer angle.

The Fibula.—The lower end of the fibula is laterally compressed. Its antero-posterior is twice its other diameter. There are on the outer side an anterior and a posterior ridge and a smaller one on the plane surface between. The facet for the calcaneum is oblong-oval or hastate, terminating posteriorly in a point. There is a posterior concave surface and a smaller anterior convex one. The facet for the astragalus is different from that of *Diplopus* (Kowalevsky, 1873, Pl. XXXV, Fig. 3), being more like that of

Oreodon. It is a lobe extending backward and upward and is broadly rounded at the extremity, not forming a half crescent as in *Diplopus*. It has no raised border or ridge projecting over the upper edge of the outer ridge of the proximal trochlea, as in the specimen No. 11162 of the Princeton Collection, the foot of which is figured in Scott's paper (1895, Pl. XXIV, Fig. 9). This articular surface occupies an elevated plane. The posterior side of this elevation is higher than the anterior.

The Tarsus.—The tuber of the calcaneum is most like that of *Oreodon*, but is much more robust in proportion to its length, especially so at the upper extremity. It is like that, too, in having no tuberosity or accessory facet on the sustentaculum, the inner border of which is a sharp angle all around.

The astragalus is longer in proportion to its width than in *Agriochærus*, but much shorter than in *Hyopotamus* or even *Oreodon*. In other respects it differs little from that of *Oreodon*. The oblique ridge above the calcaneal facet is not so prominent. As in *Oreodon*, there is a faint ridge defining the inner boundary of the facet for the calcaneum, but no massive ridge with an accessory facet as in *Hyopotamus* or *Agriochærus*.

The cuboid is much like that of *Oreodon*, but the calcaneal notch is very shallow, not descending so low as in that genus. In *Hyopotamus* it descends still lower. As seen from the front the notch occupies only one-third the width of the cuboid, and it apparently did not reach backward more than half the antero-posterior thickness of the bone. The cuboid is more regular in outline and much nearer a cube than in *Hyopotamus*, *Agriochærus* and *Oreodon*.

The navicular is more like that of *Hyopotamus*, but there is no plantar hook. Behind the proximal articular surface there are two lobes, as a valley runs down the plantar side. The inner lobe is the larger, projecting backward, so that the inner length of the bone is greater than that in *Hyopotamus*. The distal surface is nearly a plane surface, with the exception of a small median inner convexity. The inner side is more regular than in *Hyopotamus*.

The ectocuneiform is nearly like that of *Oreodon*. There is a small facet for metacarpal II, which has two faces, one more concave than the other. Above this is a small triangular facet for the mesocuneiform. On the plantar side there is a wide groove or valley, passing obliquely downward and inward from the proximal to the distal surface.

The tarsus, as far as preserved, is characterized by its plainness and lack of complication. Unless the meso- and entocuneiforms were larger than common, there must have been a large median plantar space unoccupied by tarsal bones. We have not the proximal ends of the metacarpals, so it cannot be ascertained whether there were any posterior prolongations filling this space or not.

There are no complete metapodials. There are the proximal ends of one of the smaller ones and the distal ends of eight of various sizes. The proximal portion of the smaller metapodial, compared with the median ones, is larger proportionally than in the pes of *H. brachyrhyncus* (?) (Princeton Coll., 11162). The head is thick transversely, triangular in section, conical at the top and larger than the shaft. The shaft, a little below the head, is transversely oval. The distal ends of three of the median metapodials are much like those of *Hyopotamus*, but the dorsal surfaces of the trochlea are not so convex or the groove above so deep, and the trochlea are not bent in toward the plantar side as in *Oreodon* or *Agriochaerus*. The distal ends of two lateral metapodials are symmetrical. They are quite thick and do not appear to have been in close contact with the median ones. There was probably either a hallux or a polléx, as there are two distal ends of very small metapodials.

There are several portions of phalanges and two middle ones nearly complete. The latter are short. The proximal articulating surfaces are slightly concave and separated by a low median convexity. The distal facets have a shallow groove. A lateral ungual is asymmetrical. Its dorso-plantar is greater than its transverse diameter. It has approximately the form and size of one of the median ones of *Oreodon culbertsoni*, but it is shorter and the proximal facet is divided into two unequal areas. One of the median unguals is only a little thicker planto-dorsally, but much broader. The anterior part is gone, but so far as shown the inner margin is nearly straight, while the outer curves inward toward the tip.

DISCUSSION OF RELATIONSHIP OF ARRETOTHERIUM.

Until more complete material of this animal is found, or that of related forms, it would be unwise to form a judgment as to its relationship. We can see resemblances, but these are far from being proof of relationship. There is enough preserved to show that it is very different from any other American genus at least. The skull, so far as preserved, is suggestively similar to that of *Hyopotamus*. The molars, too, aside from the absence of the protoconule, resemble those of *Hyopotamus*. They seem to be much like those of the Indian *Merycopotamus*. The premolars are different from those of *Hyopotamus*. The atlas is not much like anything I know. The lower end of the fibula, the calcaneum, astragalus and cuboid are similar to *Oreodon*. The navicular and the metacarpals and phalanges appear to be more like those of *Hyopotamus*. There is no evidence of relationship to *Agriochaerus*.

Measurements.

	M.
Length of molar-premolar series arranged, without diastema; left side. ....	.130
Length of incisor (I ³ ?).....	.0074
Width of incisor (I ³ ?).....	.004

	M.
Height of incisor (I^3 ?), crown.....	.006
Length of canine.....	.016
Width of canine.....	.009
Height of canine.....	.035
Length of P^1.....	.0092
Width of P^1.....	.004
Height of P^1.....	.006
Length of P^2.....	.0135
Width of P^2 , middle.....	.008
Height of P^2.....	.011
Length of P^3.....	.017
Width of P^3.....	.014
Width of P^3 , protocone.....	.0085
Height of P^3.....	.013
Length of P^4.....	.016
Width of P^4.....	.020
Height of P^4.....	.014
Length of molar series.....	.072
Length of M^1.....	.0185
Width of M^1.....	.020
Length of M^2.....	.024
Width of M^2.....	.0255
Length of M^3.....	.0285
Width of M^3.....	.0295
Height of M^3.....	.0190
Length of M^2 , right side.....	.255
Width of M^2 , right side.....	.027
Length of M^3 , right side.....	.029
Width of M^3 , right side.....	.030
Width of foramen magnum, about.....	.026
Width of occipital condyles, about.....	.055
Width of neural canal of atlas.....	.030
Width of anterior cotyles of atlas.....	.057
Width of odontoid process of axis.....	.020
Thickness of odontoid process of axis at base.....	.012
Diameter of distal end of tibia, transverse.....	.0415
Diameter of distal end of tibia, dorso-plantar.....	.0235
Diameter of distal end of fibula, transverse.....	.0103
Diameter of distal end of fibula, dorso-plantar.....	.0207
Length of tuber of calcaneum above astragalar facet.....	.043
Diameter of tuber of calcaneum in middle, transverse.....	.0135
Diameter of tuber of calcaneum in middle, dorso-plantar.....	.023
Length of astragalus.....	.0435
Width of astragalus.....	.027
Thickness of astragalus, dorso-plantar.....	.024
Length of cuboid, anterior.....	.020
Width of cuboid, transverse.....	.0212
Thickness of cuboid near top.....	.024

	M
Length of navicular.....	.021
Width of navicular.....	.022
Thickness of navicular, dorso-plantar .....	.0327
Length of ectocuneiform .....	.012
Width of ectocuneiform .....	.020
Thickness of ectocuneiform .....	.014
Width of a median metapodial just above trochlea.....	.018
Thickness of same .....	.015

EXPLANATION OF PLATE IX.

Figs. 1-3. *Arctotherium acridens*, gen. et sp. nov. Natural size. From Blacktail Deer creek.

Fig. 1. Upper teeth of right side. Outer view.

Fig. 2. The same, from below. In Figs. 1 and 2, premolars 3 and 4 are restored from left side. The position and arrangement of the antemolars is conjectural, as they were not found in place.

Fig. 3. Left tarsus with distal extremities of tibia and fibula. Navicular restored from right side.

Fig. 4. *Agriochærus* (?) *maximus*, sp. nov. Natural size. Molar-premolar series from the right side. From Pipe-stone creek.

Figs. 5, 6. *Limnenetes platyceps*, gen. et sp. nov. Natural size. From Thompson creek, near Three Forks.

Fig. 7. *Bathegenys alpha*, gen. et sp. nov. Spec. No. 48. Anterior of left mandibular ramus. Natural size. Pipe-stone creek.

Fig. 8. *Bathegenys*. Spec. No. 66. Another individual and perhaps a different species from Fig. 7. The last three premolars and the first molar. Natural size.

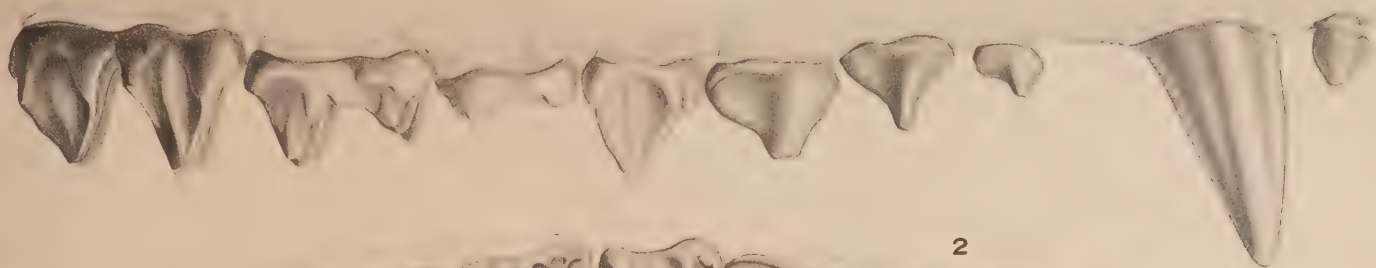
Fig. 8a. The same, with teeth magnified four diameters.

Fig. 9. *Cylindrodon fontis*, gen. et sp. nov. Left mandibular ramus. Natural size. Pipestone creek.

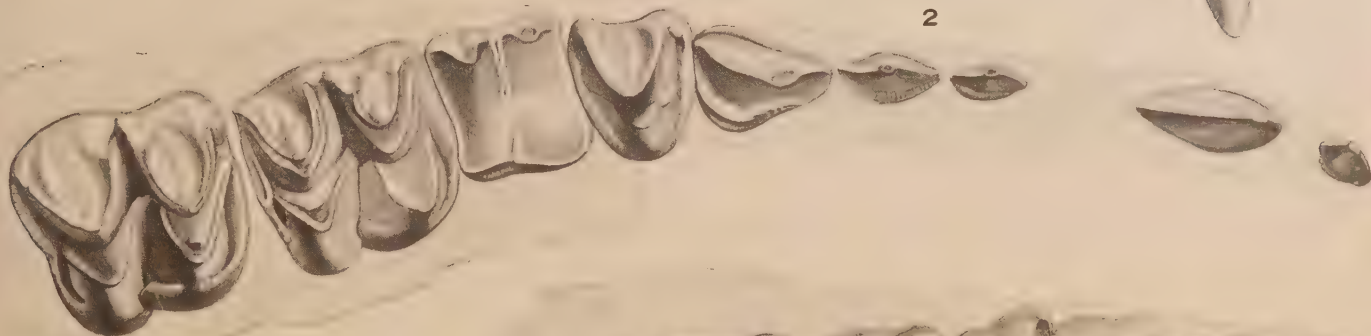
Fig. 9a. The same. Enlarged three diameters.

For "Literature," etc., see page 279.

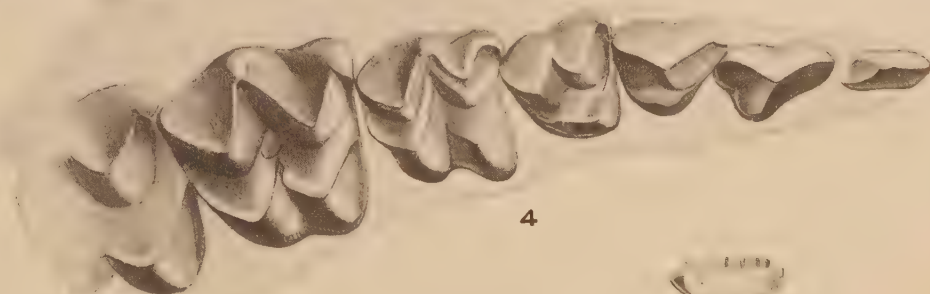
1



2



4



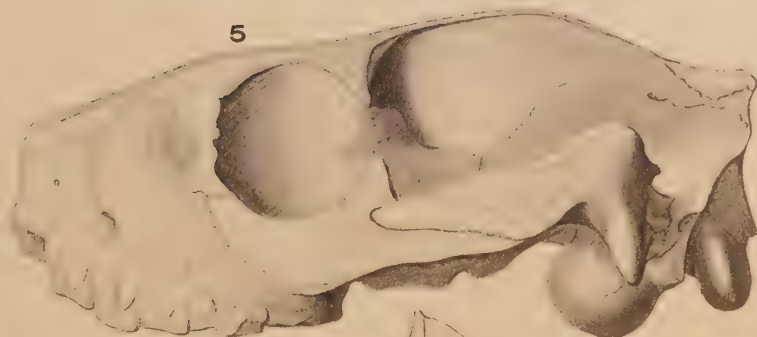
9



9a



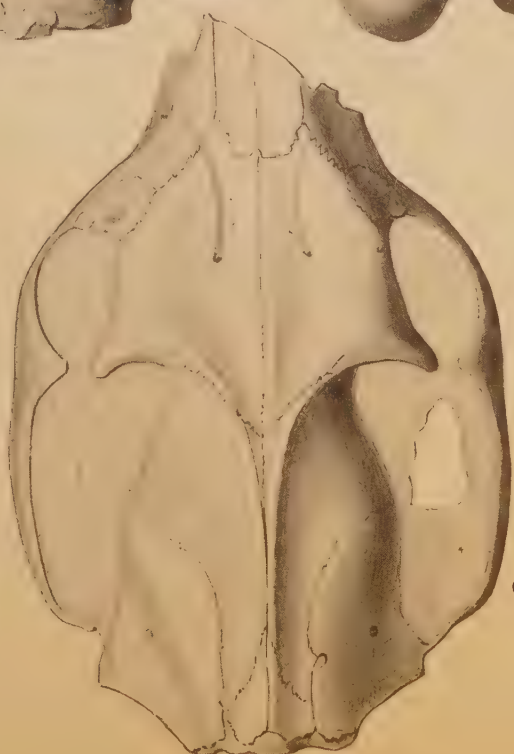
5



3



6



8a



8



7



LITERATURE.

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- 1883, (1884.) — Tertiary Vertebrata. Rep't U. S. Geol. and Geog. Survey of the Territories, Vol. III.
- 1899, (1900.) DOUGLASS, E.: The Neocene Lake Beds of Western Montana. University of Montana.
1900. — New Species of *Merycochoerus* in Montana. Amer. Journ. of Science, Dec., 1900.
1901. — The same. Jan., 1901.
1847. FALCONER, H., and CAUTLEY, P. T.: Fauna Antiqua Sivalensis.
1891. FILHOL, H.: Etudes Mammiferes Fossiles de St. Gerard le Puy.
- 1873, 1874. KOWALEVSKY, W.: On the Osteology of the *Hyopotamida*. Phil. Trans. of the Royal Soc. London, Vol. 163.
1869. LEIDY, J.: Extinct Mam. Fauna of Dakota and Nebraska. Journ. Acad. Nat. Sci. Phila.
1894. MARSH, O. C.: Miocene Artiodactyla from the Eastern Eohippus Beds. Amer. Journ. Sciences, Aug., 1894.
1893. SCOTT, W. B.: The Mammalia of the Deep River Beds. Trans. Amer. Phil. Soc., New Series, Vol. XVII.
1895. — The Structure and Relationships of *Ancodus*. Journ. Acad. Nat. Sci. Phila., Vol. IX, Part IV.

LIST OF SPECIES DESCRIBED WITH THE SPECIMEN NUMBER.

- No. 36. *Ictops acutidens*, sp. nov.
- No. 37. *Eumys minor*, sp. nov.
- Nos. 38 and 39. *Cylindrodon fontis*, gen. et sp. nov.
- No. 40. *Sciurus jeffersoni*, sp. nov.
- No. 41. *Steneofiber hesperus*, sp. nov.
- No. 42. *Steneofiber complexus*, sp. nov.
- Nos. 43, 44 and 45. *Palæolagus temnodon*, sp. nov.
- No. 46. *Hyænodon montanus*, sp. nov.
- No. 47. *Hyænodon minutus*, sp. nov.
- Nos. 48 and 66. *Bathysgenys alpha*, gen. et sp. nov.
- No. 49. *Limnenetes platyceps*, gen. et sp. nov.
- No. 50. *Limnenetes* (?) *anceps*, sp. nov.
- No. 56. *Oreodon robustum*, sp. nov.
- No. 57. *Eucrotaphus helenæ*, sp. nov.
- No. 58. *Agriochærus maximus*, sp. nov.
- No. 59. *Agriochærus minimus*, sp. nov.
- No. 60. *Arretotherium acutidens*, gen. et sp. nov.
- No. 62. *Colodon cingulatus*, sp. nov.
- No. 63. *Colodon*, sp.

ARTICLE VI.

RESULTS OF OBSERVATION WITH THE ZENITH TELESCOPE OF THE SAYRE OBSERVATORY FROM APRIL 1, 1876, TO DECEMBER 27, 1893.

BY CHARLES L. DOOLITTLE.

Read April 4, 1902.

In presenting for publication the definitive results of the series of Zenith Telescope observations at the Sayre Observatory, mention should be made of the financial assistance rendered by the Trustees of the Gould Fund of the National Academy and by Mr. Robert H. Sayre, the founder of the Observatory. Without this aid the final discussion must have been deferred indefinitely.

Among those who at different times have assisted in the work of computation, I wish particularly to mention Messrs. Henry C. Coffeen, H. J. Woods, Henry B. Evans and Eric Doolittle.

C. L. DOOLITTLE.

In Volume XX, TRANSACTIONS OF THE AMERICAN PHILOSOPHICAL SOCIETY, Article III presents the results of observation with the Zenith Telescope of the Sayre Observatory from January 19, 1894, to August 19, 1895. The brief historical statement there given as to the inception and progress of the investigation does not require repetition.

The present communication consists of three parts, as follows:

I. Investigation of the coordinates of the stars employed in the latitude work at the Sayre Observatory.

II. Results of latitude determination from 1876 to 1891.

III. Results of latitude and aberration from observations extending from October 10, 1892, to December 27, 1893.

I.

The star list is the result of a joint investigation undertaken by Henry B. Evans and myself. Of the 254 stars, 74 are found in the new fundamental catalogue of Newcomb.* The coordinates of the remaining 180 have been deduced from what was practically all material existing at the time of the reduction.

* *Catalogue of Fundamental Stars for 1875 and 1900, reduced to an Absolute System.* Washington, 1898.

In so far as the problem of latitude variation is concerned extremely precise values of the stellar co-ordinates are not required, nor is it important to reduce them to a uniform system. In the present case, however, a preliminary reduction of the observations showed very appreciable changes in the value of the micrometer during the progress of the work. These were probably due to the wearing of the screw as time went on. It is believed that the prejudicial effect of this change has been practically removed by deriving the screw value from the latitude observations, employing intervals sufficiently small to warrant regarding it as constant during the interval.

If the latitude stars could have been selected so that the plus and minus values of the micrometer correction in each group should exactly balance, no harm would follow if small errors of the screw were disregarded. This condition cannot, however, be fully satisfied, at least not for any considerable time, as precession would soon destroy the equilibrium if such existed.

In case this method of treatment is to be free from objection, the Declinations employed must have a high degree of precision. For this reason the matter has received a greater amount of attention than would have been necessary otherwise.

It is hoped, moreover, that the results may prove valuable in lines of investigation other than that which was its immediate object. With this end in view the Right Ascensions have been reduced with the same care and thoroughness as that given to the Declinations. This part of the investigation is the work of Mr. Evans.

The system adopted is that of Auwers, as found in the *Astronomische Nachrichten*, Vol. 134, p. 33. It is not to be understood that this system is considered superior to that of Newcomb; but since Auwers' system has been more commonly employed in this class of investigations, it was thought best to retain it here for the sake of uniformity.

Authorities.

In the list of catalogues employed it is not thought necessary to give more than the names of those which are generally well known. The works themselves should be found in every astronomical library. In case they are not readily accessible, further information regarding them may be obtained from Newcomb's *New Catalogue of Fundamental Stars*, Davis' *Declinations and Proper Motions of Fifty-six Stars*, and Boss' *Declinations of Fixed Stars*.

In case of all catalogues for which Auwers gives systematic corrections, these have been applied. In other cases such corrections have been derived indirectly through the systems of Newcomb or Boss. Where recourse has been had to other methods, mention of the process is found in the accompanying notes. In some of the recent catalogues the uncorrected places have been employed. For the sake of completeness and uniformity,

however, such corrections have been applied in all cases where they were available, although it would seem that any one who has had occasion to examine somewhat closely into this subject, must agree with Newcomb's conclusion that the correction for systematic errors has in recent times been carried too far.

As the Declinations were reduced in advance of the Right Ascensions, a number of catalogues became available for the latter which were not employed for the former. It is also to be observed that the list embraces several catalogues which give one coordinate only. Where the name is followed by the symbol α , the catalogue has been employed only for the Right Ascensions; when followed by the symbol δ , only for the Declinations.

In the explanatory notes s designates the systematic correction in Right Ascension; s' designates the systematic correction in Declination; p designates the weight of the Right Ascension; p' designates the weight of the Declination; t the mean date of observation. The system of weights employed will be spoken of in connection with the method of reduction.

List of Catalogues.

1. BRADLEY. 1755. Neue Reduction der Bradley'schen Beobachtungen aus den Jahren 1750 bis 1762. Von Arthur Auwers. St. Petersburg, 1888.
2. MAYER. 1755. Tobias Mayer's Sternverzeichniss nach den Beobachtungen auf der Göttinger Sternwarte in den Jahren 1756 bis 1760. Neu bearbeitet von Arthur Auwers. Leipzig, 1894.
3. FEDORENKO's Lalande. 1790. Positions Moyenne pour l'Epoque de 1790,0 des Etoiles Circumpolaire, dont les observations ont été publiées par Jérôme de Lalande dans les Mémoires de l'Académie de Paris de 1789 et 1790. Par Ivan Fedorenko. St. Pétersbourg, 1854. $s = \frac{1}{2}$ (Åbo + Bessel's Bradley); p same as 2; t from Histoire Céleste.
4. LALANDE. 1800. A Catalogue of those Stars in the Histoire Céleste Française of Jérôme de Lalande for which tables of reduction to the epoch 1800 have been published by Prof. Schumacher. Francis Baily, Esq. This catalogue was used for a few stars where other early authorities were wanting or doubtful. For declinations the places were taken directly from Baily's Catalogue. $p' = 0.1$. For right ascensions Von Asten's tables were used. p same as 2; t from Histoire Céleste.
5. BOSSERT (α). 1800. Supplément à l'Histoire Céleste de Lalande. Catalogue de 3950 étoiles ramenées à l'équinoxe de 1800. Par M. J. Bossert. Paris, 1892. p same as 2.
6. D'AGELET. 1800. Reduction of the Observations of Fixed Stars made by Joseph Lepaute d'Agelet at Paris in 1783-1785, with a catalogue of the Corresponding Mean Places referred to the equinox of 1800,0. By B. A. Gould. Washington, 1866.

$$s = 0^{\circ}.12.$$

$$s' = \text{Piazzi} - 1''.42 \quad 0^{\text{h}} \text{ to XII}^{\text{h}}.$$

$$s' = \text{Piazzi} + 1''.22 \quad \text{XII}^{\text{h}} \text{ to XXIV}^{\text{h}}.$$

$$p \text{ same as 2.}$$

7. PIAZZI. 1800. Præcipuarum stellarum inerrantium Positiones Mediæ Ineunte Sæculo xix ex observationibus habitas in Specula Panormitana ab anno 1792 ad annum 1813. Panormi, 1814. t from original observations. Right ascensions of stars north of 65° declination not used.
8. GROOMBRIDGE. 1810. A Catalogue of Circumpolar Stars deduced from the observations of Stephen Groombridge at Blackheath Observatory. Edited by George Biddell Airy, Esq. London, 1838.

9. DORPAT (*a*). 1814. F. G. W. Struve. *Observationes Astronomicas Institutas in Specula Universitatis Cæsareas Dorpatensis*, Vol. I.
10. DORPAT (*a*). 1815. *Catalogus I*.
11. KOENIGSBERG (*a*). 1815. *Bearbeitung von Bessels Beobachtungen am Dollond'schen Mittagsfernrohre in den Jahren 1813-19*. Von Dr. Fritz Cohn. *Königsberg Beobachtungen*, 39 Abtheilung. $s = 0$.
12. WEISSE-BESSEL (*δ*). 1825. *Bessel's Zone observations reduced by Maximillian Weisse*. This was used for a few declinations, usually those for which early determinations were wanting. $p = 0.1$.
13. SCHWERD-OELTZEN (*a*). 1828. The positions were taken from Carrington, No. 43.
14. ÅBO. 1830. *DLX, Stellarum Fixarum Positiones Mediæ ineunte anno 1830 ex observationibus Aboæ habitas deduxit*. Fredr. Guil. Aug. Argelander. *Helsingfors*, 1835. t from Davis, *Ast. Journal*, No. 328.
15. PEARSON (*δ*). 1830. *Dr. Pearson's Catalogue of 520 Stars within 6° North and South of the Ecliptic*. *Memoirs R. A. S.*, Vol. xv, p. 97. London, 1846. $p' = 0$; 0.1. $s' = 0$.
16. CAMBRIDGE. 1830. *Airy's First Cambridge Catalogue*. *Memoirs R. A. S.*, Vol. xi. London, 1859.
17. FALLOWS (*a*). 1830. *Results of Observations made by the Rev. Fearon Fallows at the Royal Observatory, Cape of Good Hope, in the Years 1829-31*. *Memoirs R. A. S.*, Vol. xix, p. 1.
18. POND. 1830. *A Catalogue of 1112 Stars from Observations at Greenwich from 1816 to 1833*. London, 1833. t was obtained from the original observations in *Greenwich Yearly Results*.
19. STRUVE. 1830. *Stellarum Fixarum imprimis duplicium et multiplicium pro epocha 1830*. *Petropoli*, 1852.
20. WROTTESELEY (*a*). 1830. *A Catalogue of the Right Ascensions of 1318 Stars*. By John Wrottesley, Esq. *Memoirs R. A. S.*, Vol. x.
21. MONTOJO (*a*). 1835. *Mean Positions of the Stars contained in "Mr. Baily's Address" as determined at San Fernando*. *Memoirs R. A. S.*, Vol. xii, p. 238.
22. MADRAS. 1835. *A General Catalogue of the Principal Fixed Stars from Observations made at the Honorable East India Company's Observatory at Madras in the years 1830-43*. By Thomas Glanville Taylor. Madras, 1844.
23. RÜMKE. 1836. *Mittlere Oerter von 12,000 Fixsternen für den Anfang von 1836, abgeleitet aus den Beobachtungen auf der Hamburger Sternwarte von Carl Rümker*. Hamburg, 1852.
24. KÖLLER (*a*). 1838. Extract from a letter from M. Marian Köller, Director of the Observatory at Kremsmünster . . . accompanying a Catalogue of 208 Stars. *Memoirs R. A. S.*, Vol. xii, p. 373.
25. ARMAGH. 1840. *Places of 5345 Stars observed from 1828 to 1854 at the Armagh Observatory*. By Rev. T. R. Robinson. Dublin, 1859.
26. SANTINI (*δ*). 1840. *A Catalogue of 1677 Stars included between the Equator and Ten Degrees of North Declination, observed at the Royal Observatory of Padua*. By Prof. Giovanni Santini. *Memoirs R. A. S.*, Vol. xii, p. 273. $p' = 0$; 0.1; 0.2.
27. CAPE of Good Hope. 1840. *The Cape Catalogue of Stars deduced from observations made at the Royal Observatory, Cape of Good Hope, 1834 to 1840, and reduced to the epoch 1840 under the superintendence of E. J. Stone*. Cape Town, 1878.
28. GILLISS (*a*). 1840. *Catalogue of Twelve Hundred and Forty-eight Stars observed at Washington between October, 1838, and July, 1842*. Washington, 1846.
29. GREENWICH. 1840. *Catalogue of 2156 Stars formed from the Observations made from 1836 to 1841 at the Royal Observatory, Greenwich*. London, 1849.
30. OELTZEN's Argelander (*a*). 1842. *Annalen der K. K. Sternwarte in Wien*. Bd. i. Wien, 1851. s same as Åbo; p same as Rümker; t from original zones.
31. GREENWICH. 1845. *Catalogue from observations from 1842 to 1847*.
32. PARIS. 1845. *Catalogue de l'Observatoire de Paris. Étoiles observées aux Instruments Méridiens de 1837 à 1853*.
33. POULKOVA (*a*). 1845. *Étoiles observées occasionnellement*. St. Pétersbourg, 1875.
34. RADCLIFFE. 1845. *The Radcliffe Catalogue of 6317 Stars chiefly Circumpolar reduced to the Epoch 1845*. Formed from the Observations made at the Radcliffe Observatory under the Superintendence of Manuel John Johnson. Oxford, 1860.

35. OUDEMANS (δ). 1849. *Dissertatio Astronomica Inauguralis exhibens Observationes ope Instrumenti Transitarum partabilis institutas*. . . . Lugdini-Batavorum, 1852.
36. CAPE OF GOOD HOPE. 1850. Catalogue of 4710 Stars for the Epoch 1850, from Observations made at the Royal Observatory, Cape of Good Hope, during the Years 1849 to 1852, under the Direction of Sir Thomas Maclear.
37. GILLISS. 1850. A Catalogue of 1963 Stars and of 290 Double Stars observed by the U. S. Naval Astronomers during the Expedition to the Southern Hemisphere. Appendix i to Washington Yearly Observations for 1868.
38. GREENWICH. 1850. Catalogue of 1576 Stars formed from Observations made during Six Years, from 1848 to 1853, at the Royal Observatory, Greenwich.
39. MADRAS. 1850. A Subsidiary Catalogue of 1440 Stars selected from the British Association Catalogue, reduced to Jan. 1, 1850, from Observations made at Madras in the Years 1849-53. Madras, 1854.
40. RÜMKER. 1850. Neue Folge der mittleren Oerter von Fixsternen für den Anfang von 1850, abgeleitet aus den Beobachtungen auf der Hamburger Sternwarte von Carl Rümker. Hamburg, 1852-59.
41. SONNTAG(α). 1850. Mittlere Oerter für 1850 von Vergleichsternen zum Cometen I 1850. *Ast. Nach.*, Bd. xxxiv. p same as 32; $s = .050$.
42. WROTTESELEY (α). 1850. A Catalogue of the Right Ascensions of 1009 Stars contained in the Catalogue of the British Association for the Advancement of Science. . . . By Lord Wrottesley. *Memoirs R. A. S.*, Vol. xxiii.
43. CARRINGTON. 1855. A Catalogue of 3735 Circumpolar Stars observed at Redhill in the years 1854, '55 and '56 and reduced to the Mean Position for 1855. By Richard Christopher Carrington. p same as 13.
44. MADRAS. 1855. A Catalogue of 317 Stars . . . deduced from Observations at Madras. *Memoirs R. A. S.*, Vol. xxii.
45. MOESTA. 1855. Observaciones Astronómicas hechas en el Observatorio Nacional de Santiago de Chile en los Años de 1853, 1854 y 1855. Vol. i. Santiago, 1859.
46. MOSCOW. 1855. Catalogue des étoiles observées par M. Drachoussoff. *Annales de l'Observatoire de Moscow*, Vol. vi. s same as Nautical Almanac; p same as 53.
47. POULKOVA. 1855. Positions Moyenne déduites des observations faites au cercle méridien 1840-1869 et réduites à l'époque 1855, 0. Observations de Poulkova, Vol. viii. St. Pétersbourg, 1889.
48. CAPE OF GOOD HOPE. 1860. The Cape Catalogue of 1159 Stars, deduced from Observations by Sir Thomas Maclear at the Royal Observatory, Cape of Good Hope, 1856 to 1861. Cape Town, 1893.
49. SANTINI (δ). 1860. Posizioni Medie di 1,425 Stelle, dedotte dal osservazioni fatte dal defunto Prof. Trettenaro 1861-65. Venezia, 1870. $p' = 0; 0.1; 0.2$.
50. GREENWICH. 1860. Seven Year Catalogue of 2022 Stars deduced from Observations extending from 1854 to 1860 at the Royal Observatory, Greenwich.
51. MOSCOW. 1860. Resultate aus der Zonen-Beobachtungen am Meridian Kreise der Moskauer Sternwarte während der Jahre 1858-69. I Zone 0° - 4° . *Memoirs de l'Académie Impériale des Sciences de St. Pétersbourg*, viii Série: Classe Physico-Mathématique, Vol. I, No. 5. s same as Poulkova, 1855; p same as 53.
52. PARIS. 1860. Catalogue de l'Observatoire de Paris. Etoiles observée de 1854 à 1867.
53. RADCLIFFE. 1860. Second Radcliffe Catalogue, containing 2386 Stars deduced from observations extending from 1854 to 1861 . . . Oxford, 1870.
54. YARNALL. 1860. Catalogue of Stars observed at the United States Naval Observatory during the years 1845 to 1877. Third edition revised. . . . Washington, 1889.
55. POULKOVA (δ). 1862. Observations faites à l'Instrument des passages établi dans le Premier Vertical. Oom. Observations de Poulkova, Vol. iii, pp. 223-238.
56. GREENWICH. 1864. New Seven Year Catalogue of 2760 Stars, deduced from Observations extending from 1861 to 1867 at the Royal Observatory, Greenwich.
57. BRUSSELS. 1865. Catalogue de 10,792 Étoiles observée à l'Observatoire Royal de Bruxelles de 1857 à 1878 . . . Par Ernest Quetelet, Bruxelles, 1887.

58. POULKOVA (*a*). 1865. Ascensions droites Moyenne des étoiles occasionnellement observées pour 1865,0. Observations de Poulkova, Vol. xii.
59. SCHJELLERUP (*a*). 1865. Stjernefortegnelse indeholdende 10,000 Positioner af Teleskopiske Fixstjerner imellem -15 og $+15$ Gradus Deklination. Kjøbenhavn, 1864. *s* same as Nautical Almanac interpolated as follows: $s = 1860 + \frac{7}{15}$ (1875-1860); *p* same as 53.
60. GLASGOW. 1870. Catalogue of 6415 Stars for the Epoch 1870, deduced from Observations made at the Glasgow University Observatory during the Years 1860 to 1881 . . . By Robert Grant. Glasgow, 1883.
61. MELBOURNE. 1870. First Melbourne General Catalogue of 1227 Stars for the Epoch 1870 deduced from Observations extending from 1863 to 1870, made at the Melbourne Observatory. Melbourne, 1874.
62. GREENWICH. 1872. Nine Year Catalogue of 2263 Stars deduced from Observations extending from 1868 to 1876, made at the Royal Observatory, Greenwich.
63. ASTRONOMISCHE GESELLSCHAFT ZONES. 1875. These include all of this series of catalogues published, together with the places of those stars found in the Leyden, Lund and Dorpat Zones, those of the earlier and later Lund Zones being combined separately. *p* is taken the same as Paris, '75; *p'* = 1. throughout the series.
64. ARMAGH. 1875. Second Armagh Catalogue of 3300 Stars for the Epoch 1875, deduced from Observations made at the Armagh Observatory during the Years 1859 to 1893. . . . Dublin, 1886. *p* same as 60.
65. BECKER. 1875. Resultate aus Beobachtungen von 521 Bradley'schen Sternen am grossen Berliner Meridiankreise von Dr. E. Becker. Berlin, 1881.
66. CORDOBA. 1875. Catálogo General Argentino. Cordoba, 1886.
67. DUNSINK. 1875. Mean Places of 321 Red Stars deduced from Observations made with the Meridian Circle at Dunsink. . . Dublin, 1882. *s* = 0; *p* same as Paris, '75.
68. WASHINGTON. 1875. The Second Washington Catalogue of Stars . . . prepared under the Direction of J. R. Eastman.

s obtained through Newcomb's system.

$$\begin{aligned}
 s' &= -0''.83 \text{ from } \delta = 0 \text{ to } \delta = 40^\circ \\
 &= .00 \quad \quad \quad 40^\circ \quad \quad 50^\circ \\
 &= +.09 \quad \quad \quad 50^\circ \quad \quad 90^\circ
 \end{aligned}$$

69. GÖTTINGEN. 1875. Mittlere Oerter der in der Zonen -0° und -1° der Bonner Durchmusterung enthaltenen Sterne. . . Göttingen, 1869. *s* same as for Nautical Almanac as follows: $s = s_{1860} + \frac{8}{15}$ ($s_{1875} - s_{1860}$); *p* same as Glasgow, '70.
70. HARVARD. 1875. Catalogue of Primary and Secondary Stars observed during the years 1870-1879 with the Meridian Circle of the Harvard College Observatory. Cambridge, 1886.
71. PARIS. 1875. Catalogue de l'Observatoire de Paris. Étoiles observée de 1868 à 1881.
72. POULKOVA. 1875. Catalog von 5634 Sternen für die Epoche 1875,0 aus den Beobachtungen am Pulkowaer Meridiankreise während der Jahre 1874-1880 von H. Romberg. St. Pétersbourg, 1891.
73. STOCKHOLM. 1875. Results of meridian observations found in the first five volumes of the publications of the Stockholm Observatory. *p* same as Paris, '75.
74. RESPIGHI (*d*). 1875. Catalogo delle Declinazione Medie pel 1875,0 di 1463 Stelle comprese fra i paralleli 20° e 64° nord. . . . Roma, 1880.
75. CAPE OF GOOD HOPE. 1880. Catalogue of 12,441 Stars for the Epoch 1880 from Observations made at the Royal Observatory, Cape of Good Hope, during the Years 1871 to 1879. By Edward J. Stone. London, 1881.
76. GREENWICH. 1880. Ten Year Catalogue of 4059 Stars, deduced from Observations extending from 1877 to 1886 at the Royal Observatory, Greenwich.
77. MELBOURNE. 1880. Second Melbourne General Catalogue of 1211 Stars for the Epoch 1880, deduced from Observations extending from 1871 to 1884, made at the Melbourne Observatory. Melbourne, 1889.
78. RESPIGHI (*d*). 1880. Catalogo delle Declinazione Medie pel 1880,0 di 1004 Stelle di 1^a in 6^a grandezza comprese fra 0° e 20° nord, e 64° e 90° nord. . . . Roma, 1885.

79. MUNICH (α). 1880. Erster Münchener Sternverzeichniss erhaltend die Mittleren Oerter von 33,082 Sternen. München, Neue Annalen, Bd. i. p same as 60.
80. DE BALL (δ). 1880. Declinationen von 200 Sternen innerhalb der Zone $+49^\circ$ bis 51° , nach Beobachtungen im ersten Vertical am Passagen-instrumente der Herzoglichen Sternwarte zu Gotha. Ast. Nach., Bd. ci, 353.
81. CAPE OF GOOD HOPE. 1885. Catalogue of 1713 Stars for the Equinox 1885,0 from Observations made at the Royal Observatory, Cape of Good Hope, during the Years 1879 to 1885.
82. HAEZLER. 1885. Resultate aus Beobachtungen am Meridiankreise der Herzoglichen Sternwarte zu Gotha. Ast. Nach., Bd. cxxvii, 170. $s = 0$; $p = \frac{1}{2}$ that of 76.
83. KASAN (δ). 1885. Les Observations faites à l'instrument des passages établi dans le premier vertical. Kasan Observations for 1893.
84. KARLSRUHE. 1885. Lists found in the first four volumes of the publications of the observatory. $s = 0$; p same as Radcliffe, '60.
85. WASHBURN (δ) '84, '85. 1885. Publications of the Washburn Observatory, Vol. iv.
86. SAFFORD (α). 1885. The Williams College Catalogue of North Polar Stars. Williamstown, Mass., 1885.
87. NYRÉN (δ). 1887. Declinationsbestimmungen einiger Hellenen Sterne zwischen $+18^\circ$ und $+26^\circ$ am Pulkowaer Verticalkreise. A. N., No. 2904, Bd. 121.
88. CAPE OF GOOD HOPE. 1890. A Catalogue of 3007 Stars for the Equinox 1890 from Observations made at the Royal Observatory, Cape of Good Hope, during the Years 1885 to 1895.
89. CINCINNATI. 1890. A Catalogue of 2000 Stars for the Epoch 1890. Publications of the Cincinnati Observatory, No. 13. p same as Paris 75.
90. DUNSINK. 1890. Mean places of 717 Stars deduced from Observations made with the Meridian Circle at Dunsink. Dublin, 1896. $s = 0$; p same as 71.
91. GLASGOW. 1890. Second Glasgow Catalogue of 2156 Stars for the Epoch 1890 deduced from Observations made at the Glasgow University Observatory during the Years 1886 to 1892. Glasgow, 1892.
92. KÜSTNER. 1890. Veröffentlichung der Königlichen Sternwarte zu Bonn, No. 2. $s = 0$.
93. RADCLIFFE. 1890. Catalogue of 6424 Stars for the Epoch 1890. Formed from Observations made at the Radcliffe Observatory, Oxford, during the Years 1880-1893.
94. BATTERMANN. 1895. Resulte aus Beobachtungen von 379 Anhaltsternen und 1640 durch Anschluss bestimmten Sternen, angestellt in den Jahren 1892-1897 am Grossen Berliner Meridiankreise von Dr. H. Battermann. Berlin, 1899. $s = 0$.
95. CINCINNATI. 1895. Catalogue of 2030 Stars for the Epoch 1895. Publications of the Cincinnati Observatory, No. 14. $s = 0$; p same as 71.
96. TUCKER (α). 1895. Meridian Circle Observations of 310 Standard Stars. Publications of the Lick Observatory, Vol. iv. Sacramento, 1900.
97. TUCKER (δ). 1897. The entire list of stars was very carefully observed by R. H. Tucker, of the Lick Observatory, in the years 1896 and 1897. It was intended to publish the results of these observations in full in this connection, but the preparation of this work has been so long delayed that it now appears superfluous, in view of the fact that a much more detailed report than could be given here will appear in a forthcoming publication of the Lick Observatory. The following note is by Mr. Tucker :

"Each star was observed twice in each position of the instrument, fixed circle East and West, and the greater part of the stars above 70° were similarly observed at both culminations.
 "The places were reduced with the Declinations from the catalogue of Louis Boss, *Declinations of Fixed Stars, U. S. Northern Boundary Commission*, 1879.
 "The probable error of a single observation is $\pm 0''.18$. The probable error of observation for the mean of four, in the two positions is $\pm 0''.12$, including the effect of graduation error."

The reduction to Auwers' system has been applied and the results have been employed with a uniform weight of 3.
98. WIRTZ (δ). 1900. Bestimmung der Deklinationen von 487 Sternen und der Polhöhe der Bonner Sternwarte aus Beobachtungen . . . im Ersten Vertical. Veröffentlichung der Königlichen Sternwarte zu Bonn, No. 3.

99. DUNSINK. 1900. Mean Places of 1101 Stars deduced from Observations made with the Meridian Circle at Dunsink. Dublin, 1899. *p* same as Paris, '75.
 100. KÜSTNER (*a*). 1900. Veröffentlichung der Königlichen Sternwarte zu Bonn, No. 4.

Yearly Series.

101. 1835-1869. EDINBURGH. Astronomical Observations at the Royal Observatory, Edinburgh.
 102. 1836-1869. CAMBRIDGE. Astronomical Observations made at the Observatory of Cambridge.
 103. 1862-1876. RADCLIFFE. Results of Astronomical Observations made at the Radcliffe Observatory.
 104. 1862-1887. MADRAS. Meridian Circle Observations.
 105. 1879-1882 (*a*). BRUSSELS. Annales de l'Observatoire Royal de Bruxelles, Nouvelle Series. *s* same as Nautical Almanac; *p* same as 57.
 106. 1887-1896. GREENWICH. Annual volumes.

Method of Reduction.

Approximate positions for 1875 were obtained from whatever source was available. Many of these were the result of a previous reduction, and with very few exceptions the assumed places differed from the final values only by fractions of a second. The assumed proper motions were in part the result of a previous reduction, others were taken from Auwers' Bradley and other sources.

These assumed coordinates were then reduced to the epoch of the various catalogues in which the star was found, using for this purpose the formula

$$a = a_{1875} + \left[\frac{da}{dt} \right] (\tau - 1875) + \frac{1}{2} \left[\frac{d^2a}{dt^2} \right] (\tau - 1875)^2 + \frac{1}{6} \left[\frac{d^3a}{dt^3} \right] (\tau - 1875)^3$$

α being the Right Ascension or Declination of any star.

τ the epoch of the catalogue.

The formulæ for the differential coefficients for the epoch 1875, using the constants of Struve and Peters, are as follows, in which

α = the Right Ascension.

δ = the Declination.

μ = the Proper Motion in Right Ascension.

μ' = the Proper Motion in Declination.

$$\frac{da}{dt} = 3.07225 + [0.126115] \sin \alpha \tan \delta + \mu.$$

$$\frac{d\delta}{dt} = [1.302206] \cos \alpha + \mu'.$$

$$\frac{d\mu}{dt} = [5.988] \mu \cos \alpha \tan \delta + [4.812] \mu' \sin \alpha \sec^2 \delta + [4.99] \mu \mu' \tan \delta.$$

$$\frac{d^2a}{dt^2} = [4.63380_n] \left(\frac{da}{dt} - \mu \right) + [5.98778] \left(\frac{da}{dt} + \mu \right) \cos \alpha \tan \delta + [4.81169] \left(\frac{d\delta}{dt} + \mu' \right) \sin \alpha \sec^2 \delta + [4.9866] \mu \mu' \tan \delta + 0.000032210.$$

$$\frac{d^2\delta}{dt^2} = [4.63380_n] \left(\frac{d\delta}{dt} - \mu' \right) + [7.16387_n] \left(\frac{da}{dt} + \mu \right) \sin \alpha + [6.7367_n] \mu^2 \sin 2\delta.$$

$$\frac{d^3a}{dt^3} = [2.0987] \left(\frac{da}{dt} + \frac{\mu}{2} \right) \sin \alpha + [7.1639_n] \left(\frac{d^2a}{dt^2} + \frac{d\mu}{dt} \right) \sin \alpha + [3.0255_n] \left(\frac{da}{dt} + \mu \right) \frac{da}{dt} \cos \alpha.$$

The numbers enclosed in brackets are logarithms.

For $\frac{d^2a}{dt^2}$ the Right Ascension and Declination were reduced to 1825 and 1925, using for this purpose the first and second differential coefficients already computed. $\frac{d^2a}{dt^2}$ was then derived for these dates, the differences giving $\frac{d^3a}{dt^3}$ with all necessary precision. For checking these values the tables given by Gould* were employed from 0^h to 12^h, neglecting proper motion. From 12^h to 24^h the tables of Oppolzer† were similarly used.

As already stated the catalogue places were reduced to Auwers' system whenever the necessary corrections were available. A correction for proper motion was also applied in all cases where the necessary data could be found.

Let τ be the epoch of the catalogue,

t the mean date of observation, usually different from τ ,

μ'' the proper motion employed in forming the catalogue,

μ the proper motion assumed in this discussion,

The correction will be $(\tau - t)(\mu - \mu'') = \delta_\mu \alpha$.

It is perhaps superfluous to state that both t and μ'' are unknown in case of many of the older catalogues.

Let n be the difference between the corrected catalogue place and the assumed place, reduced as above explained to the epoch of the catalogue,

Then each catalogue furnishes an equation of the form

$$\sqrt{p}(\Delta\alpha + T\Delta\mu = mn)$$

In which p is the weight of the catalogue place,

$\Delta\alpha$ the correction to the assumed Declination, or Right Ascension,

$\Delta\mu$ the correction to the assumed proper motion,

$T = 1875 - t$.

A least square solution gives the most probable values of $\Delta\alpha$ and $\Delta\mu$.

The method of solving the equations is one very commonly employed in cases like this and is as follows:

Let t_0 be the weighted mean of the catalogue epochs, or of the epoch of observation when this differs from that of the catalogue,

t_1, t_2, \dots, t_n the epochs of the respective catalogues,

$T_1, T_2, \dots, T_n = (t_1 - t_0), (t_2 - t_0), \dots, (t_n - t_0)$

ΣpT should be zero.

* *Catálogo de Las Zonas Estelares*, Appendix, Table iv, Cordoba, 1884. In using this table it must be remembered that the value of p as given in column four should be doubled. See *Ast. Nach.*, Bd. 137, p. 295.

† *Lehrbuch zur Bahnbestimmung der Kometen und Planeten*, Vol. i, Table XII.

Then we have

$$\Delta\alpha = \frac{\Sigma pn}{\Sigma p} \quad \Delta\mu = \frac{\Sigma p Tn}{\Sigma p T^2}$$

$$\text{Check } \Sigma pvv = \Sigma pnn - (\Sigma pn) \Delta\alpha - (\Sigma p Tn) \Delta\mu$$

$$\Delta\alpha \text{ for 1875 will be the above } \Delta\alpha + (1875 - t_0) \Delta\mu.$$

An example follows which will illustrate the various steps in the process:

Star.

B A C 3140

Assumed Coordinates and proper motion for 1875.0.

$$\alpha = 9^h 7^m 10^s.87 \quad \mu = +.0056$$

$$\delta = 54^\circ 32' 11''.15 \quad \mu' = +.068$$

	Catalogue.	τ	t	No. Obs.	μ''	n	p	pt	pn	T	pT	pTn	pT^2	v
1	Bradley	1755	54.2	3	+.0056	-0.009	.3	-13.74	-0.0027	-103.22	-30.97	+0.2790	+3199.20	-0.063
2	Piazzi	1800	04.83	9		+0.261	.08	+ 0.39	+0.0209	-52.59	- 4.21	-1.0962	220.92	-0.300
3	Groombridge	1810	08.8	6		-0.244	.2	1.76	-0.0488	-48.62	- 9.72	+2.3668	471.42	+0.208
4	Dorpat	1814	14.11	2		-0.212	.2	2.82	-0.0424	-43.31	- 8.66	+1.8444	376.71	+0.179
5	Pond	1830	31.54	13		+0.070	.4	12.62	+0.0280	-25.88	-10.35	-0.7280	269.36	-0.091
6	Madras	1835		11		+0.042	.3	10.50	+0.0126	-22.42	- 6.73	-0.2814	150.08	-0.061
7	Rümker	1836		6		-0.040	.2	7.20	-0.0080	-21.42	- 4.23	+0.1720	92.02	+0.022
8	Armagh	1840	34.74	2		+0.006	.1	3.47	+0.0006	-22.68	- 2.27	-0.0138	52.21	-0.025
9	Gilliss	1840	41.85	1	+.011	-0.010	.05	2.09	-0.0005	-15.57	- 0.78	+0.0080	12.48	-0.005
10	Edinburgh	1842	42.18	5		+0.225	.5	21.09	+0.1125	-15.24	- 7.62	-1.7100	115.52	-0.239
11	Oeltzen's Arg'er	1842	42.12	1		-0.118	.05	2.11	-0.0059	-15.30	- 0.77	+0.0944	12.24	+0.104
12	Greenwich	1845	44.87	6	+.011	-0.186	.7	31.41	-0.1302	-12.55	- 8.79	+1.6368	110.88	+0.173
13	Radcliffe	1845	47.9	7	+.004	+0.103	.9	43.11	+0.0927	- 9.52	- 8.57	-0.8858	81.70	-0.114
14	Paris	1845	41.6	18		-0.043	1.1	45.76	-0.0473	-15.82	-17.40	+0.7482	274.92	+0.028
15	Poulkova	1855	47.80	5	+.0056	-0.086	1.0	47.80	-0.0860	- 9.62	- 9.62	+0.8256	92.16	+0.075
16	Greenwich	1860	59.5	3	+.004	-0.013	.9	53.55	-0.0117	+ 2.08	+ 1.87	-0.0247	3.99	+0.010
17	Radcliffe	1860	59.2	4	+.004	-0.003	.4	23.68	-0.0012	+ 1.78	+ 0.71	-0.0021	1.26	.000
18	Yarnall	1860	72.5	4		-0.112	.7	50.75	-0.0784	+15.08	+10.56	-1.1872	160.06	+0.117
19	Brussels	1865	66.00	4		+0.032	1.1	72.60	+0.0352	+ 8.58	+ 9.44	+0.3008	80.84	-0.031
20	A. G. Zones	1875	75.2	2		-0.131	.3	22.56	-0.0393	+17.78	+ 5.33	-0.6943	94.34	+0.138
21	Paris	1875	81.2	2		+0.039	.3	24.36	+0.0117	+23.78	+ 7.13	+0.2769	168.98	-0.028
22	Stockholm	1875	75.53	3		-0.130	.4	30.21	-0.0520	+18.11	+ 7.24	-0.9360	130.32	+0.137
23	Madras	1878.40	73.61	5		+0.098	.5	39.31	+0.0490	+21.19	+10.60	+1.0388	224.72	-0.089
24	Greenwich	1880	84.24	7	+.0056	+0.045	2.9	+244.30	+0.1305	+26.82	+77.78	+3.5010	2085.04	-0.032
							13.58	779.71	-0.0607		- 0.08	+5.5322	+8481.37	
							Σp	Σpt	Σpn		ΣpT	ΣpTn	ΣpT^2	

$$t_0 = \frac{779.71}{13.58} = 57.42$$

Weighed mean date = 1857.42

$$\Delta\alpha = \frac{-0.0607}{13.58} = -0.0045$$

$$\Delta\mu = \frac{5.5322}{8481.37} = +0.00065$$

$$\Delta\alpha_{1875} = -0.0045 + (0.00065 \times (1875 - 1857.42)) = +0.0069$$

Assumed α $9^h 7^m 10^s.87$

Final value $9^h 7^m 10^s.877$

Assumed μ $+0.0056$

Final value $+0.00625$

$$\Sigma pv^2 = 0.1277$$

$$\Sigma pn^2 = 0.1315$$

$$-(\Sigma pn) \Delta\alpha = -0.0003$$

$$-(\Sigma pT^2) \Delta\mu = -0.0036$$

$$\text{Check } 0.1276$$

	<i>Catalogue.</i>	τ	t	N_0 <i>Obs.</i>	μ''	n	p	pt	pn	T	pT	pT^2	pTn	v
1	Bradley	1755	52.2	6	+0.068	+0.03	.6	-28.7	+ .018	-1.05	-.630	+.662	-.019	-.28
2	Piazzi	1800	04.9	7		+0.24	.3	+1.5	+ .072	-.53	-.159	.084	-.038	+.10
3	Lalande	1800				+1.77	.0	+0.0	-.000	-.58	-.000	.000	-.000	+1.62
4	Groombridge	1810	09.5	6		-0.82	.6	+5.7	-.492	-.48	-.288	.138	+.236	-.94
5	Pond	1830	31.9	20		-0.13	1.0	+31.9	-.130	-.26	-.260	.068	+.034	-.17
6	Taylor	1835		11	+0.02	-0.51	.5	+17.5	-.255	-.22	-.110	.024	+.056	-.54
7	Rümker	1836		6		+1.30	.5	+18.0	+ .650	-.21	-.105	.022	-.136	+1.27
8	Edinburgh	1840	40.2	3		-0.02	.3	+12.1	-.006	-.17	-.051	.009	+.001	-0.03
9	Armagh	1840	52.2	5		-0.48	.5	+26.1	-.240	-.05	-.025	.001	+.012	-.46
10	Greenwich	1840	40.0	21		+0.66	3.0	+120.0	+1.980	-.18	-.540	.097	-.356	+.64
11	O' Argelander	1842				+0.26	.0	+00.0	-.000	-.16	-.000	.000	-.000	+.25
12	Greenwich	1845	44.0	32	+0.02	+0.24	3.0	+132.0	+ .720	-.14	-.420	.059	-.101	+.24
13	Radcliffe	1845	46.8	13	+0.06	-0.87	2.0	+93.6	-1.740	-.11	-.220	.024	+.191	-.86
14	Paris	1845	39.5	6		+0.41	2.0	+79.0	+ .820	-.18	-.360	.065	-.148	+.39
15	Poulkova	1855	47.8	5	+0.068	-0.55	2.0	+95.6	-1.100	-.10	-.200	.020	+.110	-.54
16	Greenwich	1860	59.5	3	+0.06	+0.05	1.0	+59.5	+ .050	+ .02	+ .020	.000	+.001	+.10
17	Yarnall	1860	59.7	8		+0.48	1.5	+89.6	+ .720	+ .02	+ .030	.001	+.014	+.53
18	Paris	1860	63.8	13		-0.81	2.0	+127.6	-1.620	+ .06	+ .120	.007	-.097	-.75
19	Brussels	1865	66.2	4		+0.45	1.0	+66.2	+ .450	+ .09	+ .090	.008	+.040	+.53
20	Ast. Gesellschaft	1875	75.2	2		-0.26	1.0	+75.2	-.260	+ .18	+ .180	.032	-.047	-.15
21	Paris	1875	81.2	2		-0.11	1.0	+81.2	-.110	+ .24	+ .240	.058	-.026	+.02
22	Respighi	1875	76.1	22		-0.12	1.5	+114.2	-.180	+ .19	+ .285	.054	-.034	-.01
23	Stockholm	1875	75.2	1		-0.26	.3	+22.6	-.078	+ .18	+ .054	.010	-.014	-.16
24	Madras	1878.4	78.6	5		+0.79	1.5	+117.9	+1.185	+ .21	+ .315	.066	+.249	+.91
25	Greenwich	1880	84.0	7	+0.068	-0.21	2.0	+168.0	-.420	+ .26	+ .520	.135	-.109	-.08
26	Kasan	1885		3	+0.068	-0.23	1.0	+85.0	-.230	+ .28	+ .280	.078	-.064	-.09
27	Tucker	1897	97.0	4		-0.42	3.0	+291.0	-1.260	+ .40	+1.200	.480	-.504	-.24
							33.1	1902.3	-1.456		-.034	+2.202	-0.749	
							Σp	Σpt	Σpn		ΣpT	ΣpT^2	ΣpTn	

$$t_0 = \frac{1902.3}{33.1} = 57.5$$

Weighted mean date 1857.5

$$\Delta\delta = -\frac{1.456}{33.1} = -0''.044$$

$$\Delta\mu' = -\frac{0.749}{2.202} = -0''.340$$

$$\Sigma pv^2 = +8.74$$

$$\Sigma pn^2 = +9.05$$

$$-(\Sigma pn) \Delta\delta = .06$$

$$-(\Sigma ptn) \Delta\mu' = .25$$

$$\text{Check} \quad 8.74$$

$\Delta\mu'$ is here the correction to the centennial proper motion.

$$\Delta\delta_{1875} = -0''.044 - (.0034 \times (1875-1857.5)) = -0''.104$$

$$\text{Assumed } \delta \quad 54^\circ \quad 32' \quad 11''.15$$

$$\text{Final value} \quad 54^\circ \quad 32' \quad 11''.05$$

$$\text{Assumed } \mu' = +0.068$$

$$\text{Final value} \quad +0.0646$$

Weights.

In case of the Right Ascensions the weights have been taken from Auwers' values, *Astronomische Nachrichten*, Bd. 151, for all authorities found there. For other cases the attempt has been made to conform as closely to this system as practicable.

For the Declinations the system of weights is nearly the same as that given by Davis.* The most noticeable differences between the weights here employed and those of Newcomb are, first, the greater value assigned by Newcomb to the Pulkova and Washington catalogues; and second, in general the greater increase in weight corresponding to an increase in the number of observations. This last feature is not usually very conspicuous in the present discussion, as there are comparatively few cases where the number of observations is large. For the purpose of comparison the weights assigned by Newcomb to the authorities employed in the above example are given below, together with such as are given by Boss† in connection with his investigation.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Wght. here used	.6	.3	.0	.6	1.0	.5	.5	.3	.5	3.0	.0	3.0	2.0	2.0	2.0	1.0	1.5	2.0	1.0	1.0	1.0	1.5	.3	1.5	2.0	1.0	3.0
Newcomb	.5			.4	1.0					3.0		4.0			5.0	1.5	2.5								2.5		2.0
Boss		.1		.3	.8	.2		.6	.3	1.5		2.5	.6	1.0	3.0	1.0	.7	3.0	1.5								

This comparison will illustrate the different conclusions which have been reached as to the relative merits of some of the authorities. It is not claimed that the weights here employed are in all cases the best, but the effort has been made to follow a consistent system throughout in order to reach results which shall be so far as possible homogeneous.

The Star List.

The list of 254 latitude stars which follows includes 74 which are found in Newcomb's new Fundamental Catalogue. The places of these have been taken directly from that publication, applying the reduction to Auwers' system as explained below. Polaris is an exception, the position being taken without change from Newcomb. There are also three stars given in Davis' paper before referred to.—*The Declinations and Proper Motions of Fifty-six Stars*—the declinations of these have been taken from that publication.

The coordinates of the remaining stars—180 right ascensions and 177 declinations—have been derived as explained in the preceding pages.

As Newcomb's system is no doubt preferable to that of Auwers' for the reason that

* *Declinations and Proper Motions of Fifty-six Stars*, pages 14–18.

† *Declinations of the Fixed Stars, Report of the U. S. Northern Boundary Commission*, Appendix ii.

it represents more closely the actual state of the celestial sphere, it is very desirable that we should be able to refer our coordinates to that system. This may be very readily done by employing the formulæ and tables given by Newcomb for passing from one system to the other. These are reproduced here for the convenience of any wishing to make the change. The reduction of the declinations to the system of Boss is also included.

In what follows *N* refers to the system of Newcomb,

A refers to that of Auwers.

On page 156 of Newcomb's memoir is given for the difference of the Equinoxes

$$N = A + ".006 + ".00100 (T - 1875)$$

Combining this with the difference depending on the Declinations, page 165, the reduction in Right Ascension for any time *T* has the form

$$N = A + \Delta\alpha + \Delta\mu \frac{(T - 1875)}{100}$$

with a similar expression for the Declination.

In the table, divisions A and B give the data for reducing the Right Ascensions and Declinations respectively from the system of Auwers to that of Newcomb; C for reducing the declinations to the system of Boss.

Declination.	A		B		C	
	$\Delta\alpha$	$\Delta\mu$	$\Delta\delta$	$\Delta\mu'$	$\Delta\delta$	$\Delta\mu'$
+ 85°			"	"	"	"
80	— .017	+ .119	— .00	+ .37	— .04	+ .30
75	— .008	+ .127	+ .03	+ .45	— .07	+ .30
70	— .000	+ .129	+ .04	+ .46	— .10	+ .27
65	+ .004	+ .127	+ .02	+ .32	— .13	+ .10
			+ .03	+ .27	— .14	— .00
60	+ .005	+ .124	+ .09	+ .26	— .10	— .10
55	+ .005	+ .123	+ .19	+ .32	— .04	— .10
50	+ .002	+ .128	+ .22	+ .36	+ .04	— .10
45	— .014	+ .111	+ .30	+ .09	+ .07	— .35
40	— .012	+ .109	+ .32	— .72	+ .08	— 1.20
35	— .009	+ .096	+ .29	— .86	+ .06	— 1.33
30	— .004	+ .090	+ .26	— .81	+ .05	— 1.22
25	+ .004	+ .091	+ .24	— .85	+ .06	— 1.18
20	+ .006	+ .093	+ .24	— .94	+ .09	— 1.27
15	+ .009	+ .094	+ .31	— 1.00	+ .15	— 1.36
10	+ .011	+ .098	+ .36	— .98	+ .18	— 1.31
+ 5	+ .012	+ .103	+ .36	— .92	+ .19	— 1.24
0	+ .012	+ .108	+ .39	— .80	+ .20	— 1.16
— 5	+ .012	+ .113	+ .42	— .75	+ .23	— 1.14
— 10	+ .010	+ .113	+ .55	— .80	+ .34	— 1.25
— 15	+ .010	+ .115	+ .74	— .72	+ .48	— 1.30
— 20	+ .009	+ .116	+ .89	— .54	+ .58	— 1.30
— 25	+ .009	+ .125	+ .99	— .44	+ .66	— 1.40

The reduction for proper motion is the second term in each of the above expressions. For example, for Declination 80°

$$\mu_N = \mu_A + .00119 (T - 1875)$$

$$\mu'_N = \mu'_A + .0045 (T - 1875)$$

$$\mu'_B = \mu'_A + .0030 (T - 1875)$$

The results of a direct comparison of the stars common to the catalogues of Newcomb and Auwers will be found in No. 3742, *Astronomische Nachrichten*, in an article by Dr. Fritz Cohn entitled "Vergleichung des Newcomb'schen Fundamentalcatalogs mit dem Auwers'schen A. G. C."

In the pages which follow the column headed *B. A. C.* gives the number corresponding to the star's place in the British Association Catalogue, with the exception of five not found in that publication. The magnitudes are from various sources and do not claim great precision. The column headed *A* gives the number of authorities employed in deducing the corresponding coordinate. Where N or D occurs in this column it implies that the corresponding coordinate is taken from Newcomb or Davis, as the case may be.

The differential coefficients include the proper motions μ and μ' in accordance with the formulæ given on page 287.

To illustrate the reduction to any epoch, let the Right Ascension and Declination of No. 3 be required for 1755:

$$1755 - 1875 = -120$$

Therefore

$$\alpha_{1755} = 0^h 10^m 33^s.963 - 120 \times 3^s.11489 + \frac{1}{2} (120)^2 \times 0^s.0002643 + 0^s.019 \times (-1.20)^3.$$

$$= 0^h 4^m 22^s.046$$

$$\delta_{1755} = 37^\circ 59' 14''.89 - 120 \times 20''.0372 + \frac{1}{2} (120)^2 \times (-0''.000295) - 0''.175 \times (-1.20)^3$$

$$= 37^\circ 19' 9''.80$$

Auwers' Bradley gives

$$\alpha = 0^h 4^m 22^s.08$$

$$\delta = 37^\circ 19' 10''.0$$

Definitive Positions 1875.0.

	B. A. C.	Mg	α 1875.0	δ $d\delta$	$\frac{d^2\alpha}{d\ell^2}$	$\frac{(100)^3}{6} \frac{d^3\alpha}{d\ell^3}$	μ	δ 1875.0	$\frac{d\delta}{dt}$	$\frac{d^2\delta}{d\ell^2}$	$\frac{(100)^3}{6} \frac{d^3\delta}{d\ell^3}$	μ'	A α	A δ
			^h ^m ^s											
1	16	5.1	0 3 49.785	+ 3.09580	+ .0003283	+ .025	+ .00092	45 22 35.55	+ 20.0460	-.000162	-.171	-.0054		N
2	LL 220	7.5	10 12.247	3.12214	2468	.017	+.00069	35 47 41.51	20.0845	289	.174	+.0501	9	11
3	52	5.	10 33.963	3.11489	2643	.019	-.00547	37 59 14.89	20.0272	295	.175	-.0057	23	26
4	*60	6.2	12 7 151	3.13969	3169	.023	+.00133	43 5 48 13	20.0200	328	.178	-.0062	19	19
5	99	6.5	21 28.282	3 11329	1350	.011	-.00159	18 49 21.31	19.9573	510	.173	-.0090	16	18
6	126	4.2	0 25 54.538	+ 3 35929	+ 7016	+ .070	+.00049	62 14 29.79	+ 19.9212	- 639	-.217	-.0050		N
7	194	5.6	37 25.783	3.83965	16084	.270	-.00617	74 18 15.76	19.7567	994	.319	-.0307		N
8	222	4.6	42 11.898	3.10632	785	.009	+.00444	6 54 15.47	19.6803	915	.170	-.0349		N
9	259	3.9	49 49.230	3.30849	3068	.018	+.01211	37 49 14.99	19.6203	1129	.204	+.0380		N
10	318	5.0	1 00 50.736	3.41633	3822	.022	+.01410	43 16 31.70	19.2915	1396	.223	-.0602	20	22
11	361	7.	1 6 30.266	+ 3.01720	+ 186	+ .009	-.00504	- 7 26 49.97	+ 19.1745	- 1340	-.153	-.0413	15	16
12	394	6.7	12 45.553	3 93545	9621	.085	+.00744	64 0 6.49	19.0328	1877	.331	-.0293	17	18
13	360	2.	12 59.80	20.8603	15057	+.1229	+.00127	88 38 33.81	19.0457	9659	+.0051			N
14	413	6.7	17 7.878	3.21167	1538	.009	+.00304	17 9 58.18	18.8985	1630	.182	-.0307	13	12
15	438	6.0	21 57.528	4.35677	14364	.157	+.02478	69 37 13.22	18.7107	2318	.436	-.0748		N
16	459	7.0	1 25 55 826	+ 3.17059	+ 1217	+ .008	+.00105	11 14 19.72	+ 18.6672	- 1774	-.174	+.0061	12	12
17	480	4.2	29 28.033	3.49478	3635	.016	-.01629	40 46 45.47	18.1746	2010	.230	-.3709		N
18	502	4.9	33 12.472	3.51639	3603	.016	+.00127	39 56 35.06	18.3968	2109	.233	-.0217		N
19	592	5.8	50 31.460	3.26527	1637	.007	+.00101	17 12 23.78	17.7500	2286	.182	-.0171	32	32
20	611	5.6	53 46.264	4.36499	10502	.070	-.00047	63 47 5.72	17.6345	3107	.414	+.0010		N
21	656	3.1	2 2 6.635	+ 3.54883	+ 3043	+ .009	+.01168	34 23 41.61	+ 17.2389	- 2712	-.226	-.0355		N
22	706	6.	11 13.393	3.83707	4751	.014	-.00658	46 48 6.64	16.8415	3099	.277	-.0143	18	21
23	744	4.6	18 47.640	4.84970	13108	.077	-.00157	66 50 19.39	16.4952	4096	.518	+.0074		N
24	780	6.5	26 3.504	3.27527	1508	.004	-.00241	14 28 47.55	16.1580	2910	.170	+.0402	25	23
25	816	6.5	34 6.927	4.24693	6562	.015	+.00409	54 34 14.64	15.6597	3929	.344	-.0286	16	18
26	872	3.7	2 42 37.769	+ 3.51532	+ 2274	+ .002	+.00414	26 44 37.80	+ 15.1107	- 3410	-.197	-.1028		N
27	916	6.0	51 35.637	3.84960	3616	.001	-.00082	40 31 59.00	14.6504	3884	.250	-.0405	8	10
28	963	V.	3 0 2.496	3.87871	3554	.000	-.00031	40 28 20.47	14.1824	4061	.244	+.0045		N
29	981	5.0	3 13.561	3.84883	3368	-.001	-.00340	39 8 6.03	13.9878	4081	.234	+.0083	20	22
30	993	6.0	6 39.454	3.95407	3713	-.001	+.00518	42 2 5.78	13.7791	4259	.249	+.0164	14	17
31	1050	6.5	3 17 24.064	+ 6.09182	+ 17880	+ .020	+.00106	71 25 31.49	+ 13.0686	- 6798	-.747	+.0046	12	13
32	1068	3.8	20 23.777	3.24316	1167	.000	+.00305	9 17 43.01	12.8274	3687	.136	-.0366		N
33	1119	6.4	32 21.681	3.38265	1421	-.002	+.00128	16 7 42.19	12 0132	3998	.143	-.0304	23	22
34	1144	4.6	34 5.857	5.41987	10153	.026	-.00185	65 8 12.27	11.6256	6485	.493	-.0130	18	18
35	1221	6.0	49 29.036	3.53321	1598	.005	+.00340	22 6 57.66	10.7081	4390	.146	-.1052	31	28
36	1237	4.9	3 54 2.951	+ 4.95181	+ 6417	-.032	-.00335	58 48 19.96	+ 10.4740	- 6199	-.351	-.0006	14	18
37	1274	5.8	4 1 53.137	3.48607	1379	.006	+.00697	19 16 36.53	9.8497	4475	.129	-.0342		N
38	1286	5.6	5 53.405	5.23925	6978	.048	+.00063	61 31 58.83	9.5639	6755	.371	-.0136	13	16
39	1307	5.6	9 50.643	4.47574	3766	.026	+.00359	49 44 29.36	9.2099	5832	.237	-.0623	13	16
40	1364	6.5	18 9.030	3.80681	1792	.012	+.00483	31 9 16.66	8.5057	5056	.142	-.1161	17	17
41	1425	6.0	4 30 4.391	+ 4.70174	+ 3678	-.039	+.00035	52 49 39 86	+ 7.6519	- 6369	-.223	-.0166	16	16
42	1444	5.9	33 30.448	3.74561	1457	.012	+.00218	28 22 14.07	7.3602	5113	.117	-.0298	19	18
43	1486	3.3	43 3 312	3 25165	722	.005	+.03020	6 44 27.92	6.6416	4548	.072	+.0345		N
44	1496	6.0	46 30.153	7.52098	13291	.292	+.00303	74 4 17.30	6.3515	10441	.606	+.0298	11	16
45	1536	4.2	52 18.315	5.30905	4186	.077	-.00165	60 15 22.91	5.8237	7430	.232	-.0140		N
46	1555	7.0	4 56 54.749	+ 3.56872	+ 921	-.011	+.00001	21 6 1.57	+ 5.4353	- 5032	-.076	-.0156	16	16
47	1568	5.3	5 0 3.774	3.54044	836	.010	+.03669	18 28 30.56	5.2123	5062	.070	+.0272	38	38
48	1583	6.7	1 53.740	5.55689	4176	.096	-.00509	62 32 1.37	5.0380	7859	.224	+.0079	13	16
49	1598	6.8	6 30.813	9.34113	17142	.728	-.00238	78 16 57.33	4.6398	13270	.743	+.0019	12	12
50	*1611	5.0	5 6 45.382	3.13271	513	.005	-.00113	2 42 37.77	4.6206	4464	.046	+.0034	20	19
51	*1625	7.0	5 9 25 519	+ 3.50302	+ 725	-.010	-.00060	18 17 52.85	+ 4.3856	- 5003	-.058	-.0040	9	11
52	1687	1.7	18 25.625	3.21446	478	.006	-.00144	6 14 4.10	3.6099	4625	.038	-.0079		N
53	1662	6.4	22 8.816	18.55094	63412	8.022	+.01181	85 7 35.66	3.2903	26717	2.483	-.0069		N
54	1706	6.3	23 1.262	7.98044	7698	.436	-.00156	74 57 22.57	3.2342	11499	.349	+.0124		N
55	1751	5 5	29 55.061	5.99596	2712	.144	-.00177	65 37 34.15	2.5911	8678	.136	-.0337	14	17

* Maj.

	B. A. C.	Mg.	α 1875.0	$\frac{d\alpha}{dt}$	$\frac{d^2\alpha}{dt^2}$	$\frac{(100)^3}{6} \frac{d^3\alpha}{dt^3}$	μ	δ 1875.0	$\frac{d\delta}{dt}$	$\frac{d^2\delta}{dt^2}$	$\frac{(100)^3}{6} \frac{d^3\delta}{dt^3}$	μ'	A	A	
			^h ^m ^s										α	δ	
56	1789	6.0	5 33 17.560	+ 2.98760	+ .0000324	— .004	— .00026	— 3 38 10.93	+ 2.3379	— .004337	— .020	+ .0062	15	14	
57	1813	6.3	39 29.025	6.43751	2256	.195	— .00332	68 25 52.32	1.7300	9354	.107	— .0629	11	15	
58	1821	6.0	39 34.191	3.44764	383	.010	— .00070	15 46 17.27	1.7864	5015	.021	+ .0011	22	21	
59	1846	5.3	42 31.641	3.36855	333	.009	— .00190	12 36 34.46	1.5116	4902	.016	— .0158	16	16	
60	1862	6.0	45 16.259	3.40621	318	.009	— .00210	14 8 16.31	1.2898	4960	.014	+ .0018	23	23	
61	1874	7.0	5 47 50.816	+ 6.21420	+	1221	— .171	— .00295	66 59 52.43	+ 1.0172	— 9050	— .053	— .0457	11	16
62	1923	6.0	54 17.298	4.32443	258	.033	+ .00965	42 54 45.79	0.3511	6321	— .006	— .1487	23	23	
63	1942	6.0	57 58.099	4.13501	183	.027	— .00032	38 29 28.93	+ 0.1357	6031	+ .002	— .0420	16	15	
64	1970	6.5	6 2 0.277	3.61559	+	141	.013	— .00245	22 12 28.27	— 0.1745	5268	.006	+ .0008	20	19
65	2007	4.3	8 35.616	5.30028	—	399	.086	— .00012	59 3 10.51	0.7247	7721	.039	+ .0271	19	N
66	2045	5.5	6 15 54.004	+ 5.24501	—	812	— .082	— .00218	58 28 56.15	— 1.3973	— 7622	+ .064	— .0072	18	18
67	2083	6.2	22 7.380	7.61230	4089	.378	— .03654	73 47 14.26	1.9664	10989	.214	— .0337	10	11	
68	2101	7.5	22 48.877	3.62401	130	.013	— .00270	22 37 32.72	1.9910	5247	.034	+ .0021	12	13	
69	2126	4.4	26 8.672	3.24526	15	.007	— .00003	7 25 21.07	2.2870	4692	.028	— .0042	N		
70	2139	6.7	27 57.173	4.12875	506	.025	— .00071	38 32 37.82	2.4613	5965	.057	— .0215	13	13	
71	2159	5.1	6 30 24.188	+ 4.28990	—	698	— .031	— .00077	42 35 46.54	— 2.7119	— 6189	+ .069	— .0594	16	19
72	*2187	5.1	35 11.272	5.31695	2019	.084	— .00411	59 33 53.72	3.0706	7644	.135	— .0037	19	21	
73	2233	6.0	44 3.520	3.59865	389	.012	— .00132	21 54 23.21	3.8614	5133	.060	— .0298	23	21	
74	2301	6.5	55 33.689	3.81888	884	.015	+ .01101	29 32 40.18	5.6255	5402	.091	— .8112	21	18	
75	2317	6.3	7 1 33.458	11.67981	35652	1.495	+ .00525	81 28 40.56	5.3582	16407	1.498	— .0362	15	19	
76	2341	5.6	7 3 38.299	+ 4.69611	—	2349	— .044	— .00027	51 37 59.68	— 5.4925	— 6562	+ .171	+ .0048	13	14
77	2358	4.1	5 28.829	3.06513	155	.004	— .00067	— 0 17 15.48	5.6309	4264	.057	+ .0212	N		
78	2365	7.7	7 48.006	5.20696	3758	.068	— .00529	59 8 14.81	5.8709	7231	.237	— .0243	13	14	
79	2410	3.6	12 39.388	3.58903	726	.010	— .00189	22 12 37.58	6.2573	4944	.095	— .0056	N		
80	2439	5.8	17 51.282	6.30888	8341	.142	+ .00058	68 43 2.93	6.7301	8647	.438	— .0479	N		
81	2473	4.8	7 22 50.261	+ 3.34290	—	523	— .006	— .00117	12 15 47.15	— 7.1017	— 4528	+ .088	— .0099	N	
82	2488	5.8	27 26.887	4.37485	2480	.027	— .00280	46 27 12.20	7.4767	5886	.191	— .0091	11	11	
83	2509	4.9	31 0.239	3.92828	1587	.015	— .00307	34 52 7.63	7.8851	5246	.149	— .1296	N		
84	2551	3.7	36 53.965	3.63058	1096	.009	— .00233	24 41 44.71	8.2301	4790	.127	— .0515	N		
85	2616	7.0	46 18.214	4.90192	4898	.039	+ .00035	56 49 49.34	8.9950	6355	.305	— .0231	14	17	
86	2585	6.6	7 46 43.781	+ 15.27834	—	123878	— 1.757	— .00257	84 24 41.75	— 9.0370	— 19867	+ 4.573	— .0318	23	18
87	2660	5.4	53 20.442	2.99857	271	.001	— .00501	— 3 20 25.95	9.5220	3800	.087	+ .0079	21	21	
88	2676	6.3	56 27.588	3.54958	1169	.006	— .00455	22 25 9.48	9.7558	4475	.140	+ .0018	16	16	
89	2704	6.0	59 47.628	4.96971	5950	.034	— .00122	58 36 41.87	10.0901	6235	.352	— .0786	12	13	
90	2786	5.2	8 12 28.130	3.65640	1661	.006	— .00176	27 37 14.44	11.3336	4417	.169	— .3769	N		
91	2792	5.	8 14 19.908	+ 4.58132	—	4951	— .018	— .00274	53 37 12.17	— 11.1928	— 5515	+ .314	— .0999	17	18
92	2819	3.5	19 51.800	5.04253	7647	.021	— .01719	61 8 1.23	11.6083	5957	.418	— .1155	N		
93	2880	6.5	28 8.194	3.45679	1271	.002	— .00429	20 1 5.96	12.0785	3967	.158	— .0000	21	21	
94	2953	4.2	37 34.766	3.41847	1271	.001	— .00172	18 36 44.03	12.9579	3796	.160	— .2303	N		
95	2982	5.5	43 3.436	5.00819	8968	.001	— .00328	62 25 39.75	13.0708	5472	.463	+ .0237	27	24	
96	3003	6.0	8 45 53.055	+ 5.22336	—	10816	+ .007	— .00501	65 4 47.54	— 13.3693	— 5645	+ .524	— .0886	24	23
97	3052	6.0	50 36.236	3.35833	1157	.000	+ .00301	16 3 35.26	13.5503	3547	.161	+ .0371	26	23	
98	3083	6.7	56 30.430	4.25797	5131	.001	— .01300	51 19 12.87	14.0420	4384	.319	— .0793	13	13	
99	3109	6.0	9 0 29.562	3.61621	2148	.001	— .00407	30 9 19.01	14.2047	3656	.206	+ .0062	17	17	
100	3140	5.0	7 10.877	4.36340	6123	.008	+ .00625	54 32 11.05	14.5532	4300	.354	+ .0646	24	25	
101	3170	6.5	9 11 56.642	+ 3.52033	—	1924	+ .002	— .00348	26 46 37.94	— 14.9166	— 3369	+ .199	— .0167	9	11
102	3228	6.0	21 49.756	3.20010	838	.003	— .00289	8 43 56.79	15.4741	2902	.157	— .0093	13	14	
103	3231	6.0	23 3.368	5.81249	21387	.152	+ .01541	72 45 30.61	15.6072	5309	.799	— .0743	14	17	
104	3281	6.0	30 33.134	3.76960	3445	.007	— .00295	40 47 59.00	15.9282	3265	.255	+ .0113	19	21	
105	3307	6.0	34 15.307	3.73939	3391	.008	— .00689	40 19 34.69	16.1742	3164	.252	— .0402	15	17	
106	3375	7.0	9 46 9.550	+ 3.59771	—	2823	+ .009	— .00171	35 34 15.89	— 16.7336	— 2820	+ .233	— .0030	15	14
107	3397	6.0	50 3.213	3.81469	4309	.015	— .00137	46 0 31.54	16.9601	2914	.278	— .0440	9	12	
108	3468	6.0	10 3 48.030	3.57424	3096	.013	— .00551	38 1 0.17	17.5653	2452	.237	— .0340	11	12	
109	3505	3.6	9 33.103	3.64573	3827	.017	— .01532	43 32 15.51	17.8074	2378	.254	— .0372	N		
110	3495	5.6	11 9.018	9.80634	160804	6.885	— .09600	84 53 5.94	17.8886	6400	3.294	— .0540	N		

* Mean A.B.

	<i>B. A. C.</i>	<i>Mg.</i>	<i>a</i> 1875.0	$\frac{da}{dt}$	$\frac{d^2a}{dt^2}$	$\frac{(100)^3}{6} \frac{d^3a}{dt^3}$	μ	δ 1875.0	$\frac{d\delta}{dt}$	$\frac{d^2\delta}{dt^2}$	$\frac{(100)^3}{6} \frac{d^3\delta}{dt^3}$	μ'	<i>A</i> _a	<i>A</i> _{δ}
			^h ^m ^s					[°] ['] ^{''}						
111	3530	6.0	10 14 44.321	+ 3.59054	-.0003573	+ .016	-.01279	41 51 47.04	-18.1164	-.002235	+ .246	-.1404	21	21
112	3551	6.1	17 7 4.09	3.03233	159	.007	-.00501	3 26 35.23	18.0605	1838	.151	+ .0070	20	18
113	3584	6.0	22 48.377	3.52476	3229	.015	-.00202	39 33 50.76	18.2753	2035	.235	+ .0024	16	19
114	3647	5.0	33 23.690	4.17155	11213	.108	-.02817	66 22 13.50	18.7145	2150	.388	-.0752	23	25
115	3693	5.8	39 47.972	3.18389	1035	.009	-.00992	14 51 14.67	18.8904	1506	.179	-.0516	39	36
116	3725	5.1	10 45 59.573	+ 3.67412	5908	+ .042	-.00967	55 14 56.39	-19.0313	1614	+ .274	-.0136	21	23
117	3751	7.0	49 47.288	3.26704	1770	.012	-.00332	26 10 1.59	19.1295	1353	.195	-.0090	15	15
118	3787	7.8	58 35.045	3.21245	1677	.012	-.03152	25 52 40.14	19.3981	1146	.186	-.0596	17	18
119	3825	6.7	11 5 27.361	3.52927	5624	.045	-.00283	55 34 23.41	19.4987	1129	.248	-.0097	11	14
120	3877	4.0	17 24.428	3.13061	654	.010	+ .00937	11 13 3.04	19.7823	761	.175	-.0734		N
121	3914	4.1	11 23 57.710	+ 3.63952	11151	+ .154	-.00860	70 1 14.71	-19.8307	744	+ .274	-.0239		N
122	3949	6.0	31 6 7.13	3.27501	4171	.035	-.00710	51 18 38.87	19.9299	514	.202	-.0348	11	13
123	LL. 22186	7.5	37 35.183	3.14463	1757	.015	-.00382	30 16 25.28	19.9408	361	.179	+ .0176	5	5
124	4010	6.4	45 46.132	3.47944	3134	.032	+ .34093	38 36 55.24	25.7877	321	.240	-5.7721		N
125	W.B. 956	7.0	49 54.785	3.12117	2712	.023	-.00537	42 42 33.60	20.0439	114	.176	-.0091	7	8
126	4063	7.0	11 57 11.829	+ 3.06441	422	+ .010	-.00647	4 46 59.70	-20.0549	32	+ .166	-.0022	20	16
127	4070	5.7	58 25.584	3.15165	48131	3.874	-.06178	86 16 47.85	19.9778	55	.191	+ .0760	29	26
128	4074	6.0	59 20.134	3.07126	5797	.069	-.00880	63 37 53.58	20.1359	73	.168	-.0818	19	19
129	4099	6.5	12 4 9.300	3.06241	722	.011	-.00219	17 30 17.81	20.0439	167	.165	+ .0070	18	18
130	4123	3.4	9 13.914	3.00081	4260	.044	+ .01382	57 43 38.27	20.0356	263	.156	+ .0024		N
131	4141	6.	12 13 0.273	+ 3.03607	1015	+ .013	-.00284	23 43 45.16	-20.0327	337	+ .161	-.0108	20	19
132	4195	4.6	20 42.369	2.99891	1257	.014	-.00657	28 57 48.51	20.0527	480	.155	-.0803		N
133	4217	6.0	24 7.806	2.85950	2969	.030	-.03144	52 13 32.78	19.9400	519	.135	+ .0032	21	20
134	4239	3.9	28 8.244	2.59786	5412	.087	-.01261	70 28 39.03	19.8964	547	.101	+ .0069		N
135	4271	5.1	35 33.461	3.03725	165	.010	+ .00488	10 55 29.28	19.9102	771	.160	-.0969		N
136	4300	6.	12 41 58.304	+ 2.53448	3569	+ .046	-.00020	63 27 49.45	-19.7291	771	+ .100	-.0102	13	14
137	4318	7.	45 59.257	2.98460	436	.011	-.00232	17 45 15.18	19.6561	952	.151	-.0043	15	14
138	4371	6.	56 53.595	2.36184	2704	.038	-.02840	64 16 55.50	19.4285	920	.077	+ .0109	15	D
139	4403	6.7	13 3 39.125	2.95067	297*	.010	-.00589	17 30 56.71	19.2846	1261	.145	+ .0011	10	D
140	4433	5.5	8 2.768	2.72915	1348	.016	-.00529	40 48 54.77	19.1675	1245	.114	+ .0093	19	15
141	4467	5.7	13 14 42.758	+ 2.69642	1244	+ .015	-.00615	40 48 26.06	-19.0115	1338	+ .110	-.0135		N
142	4510	5.4	23 51.663	2.21159	1520	.021	-.01198	60 35 30.75	18.7026	1228	.066	+ .0240		N
143	*4562	5.8	34 42.246	2.86584	215	.009	-.00473	20 35 19.01	18.3386	1755	.128	+ .0277	28	23
144	4604	7.0	42 11.369	+ 3.09164	800	+ .007	-.00292	2 12 59.63	18.0891	2021	.158	+ .0044	12	14
145	4643	6.3	45 59.908	-2.04548	54886	-2.010	+ .02175	83 22 45.61	18.0066	1240	.668	-.0593	19	23
146	4694	7.2	14 0 53.630	+ 2.66069	374	+ .009	+ .00002	31 26 53.82	-17.4277	2028	+ .101	-.0994	17	14
147	4701	6.0	3 37.069	2.24714	626	.010	-.00533	50 2 58.10	17.1566	1753	.066	+ .0504	21	21
148	4728	6.0	9 21.039	2.42131	496	.009	-.00461	42 6 22.85	17.0451	1958	.079	-.1011	14	12
149	4758	6.0	14 39.780	2.46386	416	.009	-.00028	39 22 9.29	16.6933	2063	.081	-.0024	17	17
150	4825	6.2	29 31.903	2.45312	224	.007	-.00354	37 10 33.39	15.9886	2238	.078	-.0536	17	17
151	4841	6.0	14 33 30.806	+ 2.25487	212	+ .007	-.01069	44 10 55.50	-15.6918	2100	+ .064	+ .0293	16	19
152	4874	6.2	38 56.377	1.48735	1046	-.005	+ .00866	61 47 42.71	15.4542	1461	.045	-.0323	16	19
153	4905	4.6	45 37.472	2.76605	217	+ .005	+ .00903	19 37 14.04	15.1218	2741	.102	-.0803		N
154	4926	5.7	50 19.265	2.82767	354	+ .004	-.00299	14 57 9.49	14.7674	2851	.106	-.0009		N
155	4949	4.9	55 36.075	0.93382	2856	-.021	-.01339	66 25 50.42	14.4330	993	.058	+ .0170		N
156	4974	4.9	14 59 40.343	+ 1.97993	195	+ .003	-.03865	48 8 30.82	-14.1646	2060	+ .049	+ .0361		N
157	5000	7.2	15 5 35.112	2.42969	72	.004	-.00047	33 33 11.89	13 8331	2625	.070	-.0023	11	10
158	5072	5.3	16 48.324	2.40058	136	.004	-.00477	33 22 55.55	13 0931	2701	.065	+ .0104	16	21
159	5113	6.7	25 24.620	1.90462	376	+ .001	-.00212	48 8 35.78	12.5294	2221	.044	-.0050	15	14
160	5147	5.9	25 10.716	0.82293	2658	-.018	-.01874	64 37 46.26	12.1847	981	.057	+ .0806	15	20
161	5180	5.8	15 35 14.345	+ 2.75440	412	+ .002	+ .00032	16 25 44.63	-11.8507	3293	+ .082	-.0093	21	20
162	5210	6.5	39 26.853	1.62603	721	-.002	-.00812	52 45 22.11	11.5070	1979	.038	+ .0352	15	15
163	5236	6.0	43 25.472	2.46853	265	+ .002	-.00190	28 32 28.75	11.2549	3026	.062	+ .0011	16	19
164	5271	4.6	48 21.287	2.07185	178	+ .001	+ .03903	42 48 8.18	10.2675	2631	.042	+ .6288		N
165	5295	5.5	51 14.803	+ 2.18162	271	+ .001	+ .00323	38 18 32.54	10.5978	2743	.046	+ .0844	19	20

* Maj.

	B. A. C.	Mg.	α 1875.0	$\frac{da}{dt}$	$\frac{d^2a}{dt^2}$	$\frac{(100)^3}{6} \frac{d^3a}{dt^3}$	μ	δ 1875.0	$\frac{d\delta}{dt}$	$\frac{d^2\delta}{dt^2}$	$\frac{(100)^3}{6} \frac{d^3\delta}{dt^3}$	μ'	A_α	A_δ
			h m s											
166	B.D. 72.703	7.0	15 56 54.384	— 0.63714	+ .0007861	— .054	— .01014	72 44 57.06	— 10.2427	— .000767	+ .163	+ .0179	6	7
167	5325	6.4	57 34.955	+ 2.96095	631	.001	— .00389	5 19 56.97	10.1956	+ 3756	.086	+ .0169	19	16
168	5343	6.5	58 1.161	— 1.51902	13021	.090	+ .00588	75 55 54.43	10.1955	— 1858	.297	— .0187	15	16
169	5366	6.0	16 2 26.482	+ 2.88865	553	.000	— .00184	8 52 4.99	9.8430	+ 3711	.079	— .0015	18	17
170	5405	6.0	7 4.377	+ 2.96279	614	.001	+ .00069	5 20 31.84	9.4868	+ 3849	.081	— .0003	18	16
171	5462	5.5	16 14 24.859	— 1.80071	+ 12648	— .059	— .00052	76 11 29.11	— 8.9127	— 2293	+ .304	+ .0030		N
172	5466	3.8	16 24.391	+ 2.64326	381	.000	— .00432	19 26 52.79	8.7129	+ 3500	.057	+ .0463		N
173	5512	2.9	22 18.101	0.79905	1853	.010	— .00317	61 47 51.17	8.2369	1093	.044	+ .0554		N
174	5568	8.0	32 32.500	1.74510	533	.002	— .00274	46 52 1.83	7.4603	2390	.029	+ .0082	14	15
175	5619	5.8	39 15.046	2.21116	327	.000	— .00606	34 16 13.25	6.8496	3048	.033	+ .0709	14	15
176	5658	6.0	16 44 17.644	+ 1.22618	+ 957	— .005	+ .00315	55 37 55.19	— 6.5113	+ 1724	+ .028	— .0066	13	16
177	5703	6.3	49 55.234	2.45154	331	.001	— .00071	25 56 0.35	6.0480	3434	.035	— .0109	16	18
178	5752	5.5	57 4.066	+ 1.09339	959	— .005	— .00688	56 52 21.34	5.4073	+ 1549	.026	+ .0306	20	16
179	5780	4.4	58 50.852	— 6.38651	30769	+ .560	+ .00448	82 14 22.61	5.2927	— 8955	.924	— .0050		N
180	5774	5.9	17 1 46.818	+ 3.09194	521	— .004	— .00092	— 0 54 46.32	5.0679	+ 4385	.048	— .0281	22	21
181	5786	7.0	17 3 23.583	+ 2.47551	+ 325	— .001	— .00182	24 39 2.72	— 4.9452	+ 3519	+ .029	— .0421	13	16
182	5801	6.	5 23.866	1.14938	819	.004	— .00199	55 55 38.88	4.6969	1647	.022	+ .0358	10	10
183	5828	3.2	9 53.866	2.46114	333	.001	— .00285	24 59 16.53	4.4989	3519	.026	— .1496		N
184	5843	4.8	12 42.531	2.21177	311	.001	— .00299	33 14 9.32	4.1053	3171	.020	+ .0035		N
185	5911	5.7	23 25.523	1.58640	445	— .003	— .00092	48 21 56.97	3.2017	2297	.014	— .0149		N
186	5941	2.3	17 29 7.956	+ 2.78178	+ 333	— .002	+ .00695	12 39 9.19	— 2.9184	+ 4042	+ .021	— .2256		N
187	6006	4.9	37 41.102	— 0.36028	1077	+ .004	+ .00077	68 48 55.94	1.6344	— 513	.027	+ .3151		N
188	6122	5.8	57 21.255	— 1.04540	571	+ .021	+ .00031	72 0 59.20	— 0.2393	— 1522	+ .016	— .0078	19	21
189	6143	3.7	18 1 25.433	+ 2.84192	181	— .003	— .00546	9 32 51.52	+ 0.2215	+ 4136	— .002	+ .0969		N
190	6193	6.	8 54.682	1.99699	213	— .001	— .00345	38 44 22.70	0.7839	2902	.002	+ .0043	15	13
191	6203	5.3	18 11 45.540	+ 1.86336	+ 204	— .002	— .00170	42 7 3.70	+ 1.0309	+ 2707	— .002	+ .0024		N
192	6232	6.5	15 2.707	2.31200	192	.001	— .00198	29 36 47.62	1.3253	3356	.005	+ .0102	12	14
193	6246	6.3	17 0.418	1.40442	159	.003	— .00102	51 17 36.33	1.4358	2030	.002	— .0510	14	D
194	6258	6.0	18 33.020	1.40906	136	.003	— .00336	51 14 28.25	1.6091	2036	.002	— .0122	10	15
195	6300	5.7	21 24.823	2.48523	+ 162	.001	— .00113	23 47 3.76	2.1449	3593	.013	+ .0137	19	19
196	6348	5.5	18 30 25.204	+ 1.03378	— 86	— .004	— .00171	56 57 1.74	+ 2.6403	+ 1481	— .007	— .0137	19	10
197	6373	6.5	36 53.277	0.72915	— 385	.004	— .00151	60 35 43.03	3.2589	1034	.012	+ .0451	10	8
198	6387	4.3	40 16.953	2.57899	+ 168	.001	— .00297	20 25 41.21	3.1726	3634	.022	— .3341		N
199	6476	6.0	51 29.318	1.58105	+ 29	.002	— .00742	43 42 13.81	4.3436	2218	.012	— .1240	13	14
200	6491	3.3	54 16.088	2.24219	+ 134	.001	— .00148	32 31 9.37	4.7073	3156	.023	+ .0029		N
201	6534	5.7	19 0 12.139	+ 2.28341	+ 142	— .000	+ .00417	31 33 32.09	+ 5.1369	+ 3199	— .025	— .0706	9	11
202	6579 Pr.	6.0	8 50.808	1.55271	— 286	.002	— .01785	49 37 16.35	6.5555	2113	.022	+ .6214	20	21
203	6599	4.5	12 1.813	2.07950	+ 102	.000	— .00251	37 54 43.78	6.2136	2854	.026	+ .0140		N
204	6656	6.5	19 59.521	1.89539	+ 55	.001	+ .00067	43 8 42.92	6.8221	2569	.024	— .0362	11	13
205	6697	3.9	26 33.255	1.51300	— 248	— .002	+ .00108	51 27 51.02	7.5200	2021	.024	+ .1250		N
206	6740	4.0	19 34 26.409	+ 2.36776	+ 108	+ .001	— .00102	29 51 58.67	+ 8.0787	+ 3128	— .042	+ .0468	19	20
207	6784	5.0	41 40.937	2.27490	+ 201	+ .001	.00000	33 26 16.24	8.1687	2959	.039	— .4397	25	27
208	6830	6.0	48 26.257	1.76583	— 57	— .001	— .00267	47 36 35.63	9.1315	2249	.030	— .0070	17	20
209	6876	5.7	55 24.928	1.88461	+ 28	+ .000	+ .00112	45 25 54.75	9.6580	2367	.033	— .0197	12	15
210	6915	5.6	20 1 43.209	2.22602	+ 218	+ .002	— .02003	35 37 44.60	9.7303	2730	.044	— .4269	16	20
211	6962	4.2	20 9 22.335	+ 1.88520	+ 39	+ .001	+ .00067	46 26 17.74	+ 10.7147	+ 2277	— .036	— .0141		N
212	6998	5.3	13 51.062	2.30267	+ 191	+ .002	— .00035	34 35 35.01	11.0686	2754	.052	+ .0108	14	18
213	7037	6.0	19 32.269	0.29206	— 3835	— .029	+ .00119	68 28 49.72	11.5024	301	.077	+ .0330	17	19
214	7094	5.6	28 2.298	2.83728	— 88	+ .002	+ .00368	12 36 0.59	12.1104	3257	.092	+ .0388	20	18
215	7140	4.8	32 56.283	2.67653	+ 94	+ .003	+ .00244	20 45 48.92	12.4224	3016	.081	+ .0112		N
216	7138	5.0	20 33 0.477	+ 3.07585	— 440	+ .001	+ .00449	0 2 53.76	+ 12.4130	+ 3474	— .117	— .0029	20	19
217	7178	6.0	35 59.559	— 3.46948	— 38815	— .551	+ .01342	80 59 35.47	12.6219	— 3971	.862	+ .0019	25	21
218	7176	6.0	37 38.525	+ 1.27913	— 988	— .007	— .00011	60 3 13.32	12.8991	+ 1386	.039	+ .1673	16	14
219	7213	4.5	42 32.435	2.33413	+ 314	+ .004	— .00011	36 1 55.75	13.0627	2527	.061	+ .0026		N
220	7254	5.6	48 56.674	2.09498	+ 309	+ .004	+ .00258	44 42 32.10	13.4748	2207	.053	— .0053	13	15

	B. A. C.	Mg.	α 1875.0	$\frac{d\alpha}{dt}$	$\frac{d^2\alpha}{dt^2}$	$\frac{(100)^3}{6} \frac{d^3\alpha}{dt^3}$	μ	δ 1875.0	$\frac{d\delta}{dt}$	$\frac{d^2\delta}{dt^2}$	$\frac{(100)^3}{6} \frac{d^3\delta}{dt^3}$	μ'	A_α	A_δ								
			^h ^m ^s																			
221	7297	6.8	20 55 8.805	+	2.28855	+	385	+	.005	+	.01945	39 45 52.58	+	14.0843	+	2370	—	.060	+	.2072	12	15
222	7326	7.0	59 11.374		2.24274	+	429	+	.005	—	.00089	41 8 4.30		14.0826		2259	.059	—	.0476	16	17	
223	7380	4.1	21 9 34.505	+	2.99964	—	275	+	.004	+	.00231	4 43 55.51	+	14.6840	+	2900	.126	—	.0764		N	
224	7438	6.0	17 2.098	—	0.54914	—	13095	—	.195	+	.00906	76 29 8.40	—	15.2049	—	579	.210	+	.0105	15	18	
225	7509	7.3	28 59.097	—	0.17576	—	10728	—	.162	—	.00016	75 51 14.56	—	15.8451	—	225	.160	—	.0107	14	14	
226	7522	5.8	21 32 16.307	+	3.00552	—	226	+	.005	+	.00651	5 12 30.91	+	16.0611	+	2570	—	.135	+	.0308	19	19
227	7561	2.5	88 2.800		2.94569	—	54	+	.006	+	.00058	9 18 9.89		16.3381		2424	.129	+	.0093		N	
228	7597	5.0	41 32.269		0.75768	—	4063	—	.052	—	.01174	71 44 50.27		16.4609		547	.065	—	.0433	21	22	
229	7610	6.7	44 48.584		1.07425	—	2310	—	.026	—	.00131	69 34 17.31		16 6339		799	.050	—	.0313	19	19	
230	7641	5.6	50 50.663		2.92387	+	73	+	.006	—	.00329	11 29 0.62		16.9434		2202	.130	—	.0098	23	18	
231	B.D.59.2444	7.4	21 55 23.038	+	1.87498	+	629	+	.009	—	.01368	59 41 56.30	+	17.1664	+	1330	—	.048	+	.0044	2	3
232	7685	6.0	58 21.651		3.08735	—	444	+	.006	—	.00274	— 1 30 36.43		17.2535		2203	.154	—	.0418	22	19	
233	7712	6.0	22 1 58.058	+	2.81316	+	482	+	.008	—	.00505	21 5 42.22		17.3875	+	1942	.119	—	.0655	17	18	
234	7732 Pr.	7.5	2 36.064	—	1.82387	—	41949	—	.1214	—	.07011	82 16 2.88		17.4382	—	1430	.551	—	.0419	14	20	
235	*7760	6.2	7 47.510	+	1.37936	—	1001	—	.010	—	.00990	69 30 55.01		17.7058	+	863	.042	+	.0075	19	22	
236	7796	5.1	22 15 21.940	+	2.95157	+	186	+	.008	+	.00006	11 34 33.48	+	18.0168	+	1820	—	.139	+	.0166		N
237	7820	5.0	19 27.071		2.42089		1502	.015	—	.00164	48 50 35.16		18.1416		1421	.080	—	.0133	21	24		
238	7843	5.5	24 18.856		2.73673		1053	.011	+	.00236	31 55 59.80		18.3258		1541	.113	—	.0058		N		
239	7915	6.0	35 53.019		2.67372		1478	.014	—	.00202	39 34 22.44		18.7157		1318	.107	—	.0029	12	14		
240	7932	5.1	38 31.178		2.66317		1578	.015	—	.00220	41 9 49.01		18.8149		1270	.106	+	.0148		N		
241	7962	6.	22 44 43.689	+	2.69296	+	1680	+	.015	—	.00053	41 17 30.61	+	18.9762	+	1185	—	.110	—	.0061	15	18
242	7978	6.7	47 28.894		2.72890		1638	.015	—	.00037	39 30 12.46		19.0465		1156	.114	—	.0121	9	12		
243	8024	6.5	56 13.899		2.51745		2636	.027	—	.00138	56 26 3.21		19.2766		925	.092	—	.0064	14	12		
244	8052	4.5	23 1 1.528		2.91336		1074	.011	—	.00171	24 47 38.07		19.3660		997	.140	—	.0279	20	21		
245	8078	5.2	5 25.566		3.02596		291	.009	—	.00173	8 2 29 52		19.5022		957	.157	+	.0139		N		
246	8122	6.8	23 13 22.079	+	2.17376	+	3954	+	.068	—	.01451	73 0 21.60	+	19.6084	+	552	—	.063	—	.0321	15	15
247	8195	6.	25 8.838		2.93427		2146	.018	+	.02341	38 32 58.87		19.7497		568	.144	—	.0731	25	27		
248	8229	4.3	32 0.619		2.92399		2500	.020	+	.00139	42 34 34.12		19.9075		434	.144	+	.0026		N		
249	8252	6.5	37 0.710		2.89691		3494	.031	—	.00112	52 27 33.04		19.9492		337	.139	—	.0042	10	10		
250	8284	6.0	43 19.993		3.02431		1642	.014	+	.00403	28 8 47.79		20.0206		235	.159	+	.0194	21	19		
251	8317	7.5	23 49 18.287	+	2.97533	+	4392	+	.041	—	.00191	56 42 59.50	+	20.0216	+	116	—	.151	—	.0108	13	14
252	8324	4.8	51 24.502		3.04540		1476	.013	—	.00407	— 24 26 47.38		20.0143	+	80	.163	—	.0258		N		
253	8356	7.0	56 21.235		2.90393		19789	.714	—	.01147	82 16 38.46		20.0355	—	19	.141	—	.0162	15	15		
254	8365	6.5	23 58 39.339		3.07383		120	.010	+	.00142	— 1 11 50.15		20.0000	—	60	.167	—	.0539	23	24		

* Maj.

II.

Latitude Determination at the Sayre Observatory.

Observations for Latitude at this institution were begun April 1, 1876, and ended August 19, 1895. They may be regarded as forming four different series as follows:

First.—Determinations depending on a list of 60 pairs of stars, the observations being distributed very unequally through the years 1876, '77, '78, '85, '86, '88, '89 and '90.

Second.—A list of 109 pairs observed from December 1, 1889, to December 13, 1890, each pair with two exceptions being observed both evening and morning. Sixteen pairs were common to both the old list and the new one, but the old list was entirely

reobserved (excepting three pairs) in connection with the new one, for the purpose of connecting the two series, thus insuring continuity in the results.

Third.—Series extending from October 10, 1892, to December 27, 1893. The same list, excepting a few objectionable pairs which were replaced when possible by more favorable ones, was employed as above—107 pairs in all.

Fourth.—Observation upon 41 pairs, forming four groups, employing the method of Küstner.* All of these pairs are found in the list used in Series Three. These observations extended from January 19, 1894, to August 19, 1895. As the results of this series have already been published,† no further comment is called for in this connection.

FIRST SERIES.

The Instrument.

A Zenith Telescope of three inches aperture and forty-one inches focal length, made by E. & G. W. Blunt, of New York, was employed throughout the entire campaign. It is said to have been purchased at second-hand from the U. S. Coast Survey in 1868, or thereabout. Upon taking charge of the Department of Astronomy at Lehigh University in 1875, I found the instrument in a dilapidated condition. Before attempting any serious work it was sent to Edw. Kahler of Washington, who furnished a new level and made some other repairs.

Level Value.

This was investigated by attaching the tube to the Mural Circle of the U. S. Naval Observatory. Though the mean value may be found in this way with reasonable accuracy, the method is not adapted to investigating the question of the uniformity of curvature of the tube. Four of the six micrometers with which the circle was provided were read for each position of the bubble.

The mean of fifteen such determinations gave for one division of the level the value

$$1''.06$$

No further attention was given to the matter until 1888, when a level-trier gave the value

$$0''.80$$

* *Astronomische Nachrichten*, Bd. 126, No. 3015.

† TRANSACTIONS OF THE AMERICAN PHILOSOPHICAL SOCIETY, Vol. xx, Philadelphia, 1901.

The tube had been twice refilled in the interval. Whether from this or from some other cause there had been a change of curvature.

Except for those observations near the beginning of the period under consideration and those not far from 1888, it is obviously impossible to decide what value of the level ought to be employed. The safest plan appeared to be to exclude from the final results all those cases in which this correction was large. The limit of $1''.5$ for the older observations and $2''.0$ for the later ones was adopted. A few values were retained where these limits were slightly exceeded.

The Micrometer.

The value of one revolution of the screw employed during the different years, with the method of its determination, is as follows:

1876-'78	50.450 $\pm .009$	Nine elongations of 51 Cephei and λ Ursæ Minoris.
1885-'86	50.5133 $\pm .0084$	From the Latitude Observations.
1888	50.5633	One elongation each of 51 Cephei and λ Ursæ Minoris.

The observation of the old list in 1890 was carried on in connection with the new one. The details as to Micrometer and Level will be found in connection with the Second Series.

Method of Observing.

Previous to 1889 the Micrometer was provided with only one movable thread. One bisection of the star was made, the effort being to have the thread accurately on the star at the instant when the latter crossed the meridian as shown by the clock. This would not usually coincide with the instant of crossing the middle thread of the reticle, as it was not possible to adjust the instrument with great precision in this respect. The outstanding difference, however, was of little importance. The clock correction was determined with a small transit instrument and was always known with the requisite precision.

The level was read once, usually after bisection of the star.

A preliminary reduction of the observations up to June 20, 1877, seemed to show a tendency of the bubble occasionally to cling to the tube, thus producing fictitious level readings. After this time until the end of the work in 1878, an effort was made to overcome this difficulty, or to obtain evidence tending to show whether or not the readings were genuine, in the following manner: Whenever there was sufficient time between the stars two or more readings of the level were taken, the instrument being disturbed by

turning it slightly in azimuth after each reading. The individual readings would probably never agree exactly, even if the performance of the level were perfect, owing to want of precision in the vertical axis. Large deviations from the first reading were, however, regarded as sufficient ground for rejecting such observations.

It is perhaps an open question whether anything was gained by this procedure, as there are obvious difficulties in formulating a criterion for rejection founded on the evidence so furnished.

The work of 1885-'86 is in all essential respects a repetition of that of 1876-'78. The same star list was used with the exception of three pairs which precession had carried beyond the range of the Micrometer.

The series of 1888 was intended to be a repetition of the same procedure, with some improvements which it was hoped would add materially to the accuracy of the results. The Micrometer was thoroughly repaired and the old springs replaced with new ones. A level by Stackpole & Brother took the place of that of Kahler, which had been in use since 1876. A level-trier was also provided, with which it was proposed to make frequent tests of the sensitiveness of the tube.

Although the new level proved to be much better than the old one, it failed to meet the requirements in respect to precision, and was returned to the maker after a trial of six weeks. The difficulties in finding a tube of the required delicacy proved greater than was anticipated; a delay of nearly a year was the consequence.

Meanwhile, in the future prosecution of the work a more elaborate program had been decided upon. This included a reobservation of the old list, with the exception of the three pairs which were no longer available. It is with this part of the program that we are now concerned; that relating to the new list prepared at this time being treated in another section.

The distribution of the observations on the old star list, originally comprising 60 pairs, was as follows:

<i>Year.</i>	<i>Number of Observations.</i>	<i>Year.</i>	<i>Number of Observations.</i>
1876	137	1886	167
1877	178	1888	121
1878	12	1889	17
1885	115	1890	397
			—
			Total, 1144

A number of the older observations, in which the level corrections were large or where the readings appeared to be fictitious, were excluded for reasons already given.

These are not included in the above summary. It must not be understood that this process of exclusion was employed merely as a convenient means of rejecting those determinations which gave inconveniently large residuals. On the contrary, the residuals given by the rejected observations were in the majority of cases smaller than those of many which were retained.

As may be supposed, the accuracy of these earlier observations was far below the standard since attained in this class of work. Their value lies mainly in the fact that they precede by several years the period when the problem of Latitude variation began to attract serious notice, and it may be claimed that they had some influence in directing attention to this important subject.

The probable error of a single determination for the various periods was as follows :

	''
1876	0.578
1877	.457
1885-86	.407
1888	.366
1889-90	.234

The values of the latitude for each day of observation follow. These of course depend on the values of the declination employed, no means for adjustment being at hand. In forming the means all have been given equal weight.

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	ϕ	No.	Number Mean		ϕ	No.	Number Mean		ϕ	No.	Number Mean		ϕ	No.	Number Mean
1876 April 1	3.92	6		1885 Sept. 18	4.22	8		1889 Dec. 1	2.79	1		1890 July 5	3.66	9	
6	3.23	8	56	19	4.01	14		4	3.41	1		6	3.41	8	
8	3.37	12	3''.65	20	3.96	15		6	3.21	1		11	3.51	1	
10	3.86	1		23	3.83	12		7	2.86	2		18	3.74	5	
15	3.43	11		24	3.63	11		9	3.26	2		19	3.79	5	55
21	4.09	16		25	3.26	11		11	2.90	3	22	20	3.70	10	3''.55
27	3.77	2		26	3.54	9	115	13	3.09	1	3''.10	21	3.18	1	
				27	3.69	9	3''.72	23	3.20	2		22	3.38	8	
				28	3.73	9		26	3.47	3		30	3.58	3	
Aug. 5	3.86	10		29	3.19	7		27	2.59	1		31	3.23	5	
7	4.03	13		Oct. 3	4.16	2		1890 Jan. 18	3.07	3					
8	3.90	17	81	5	3.96	2		24	2.77	1		Aug. 3	4.09	1	
9	3.49	15	3''.56	10	3.32	2		27	3.40	1		6	4.02	6	
10	3.08	15		11	2.72	2						9	3.31	2	
11	2.93	11		16	3.71	2						10	3.17	4	
								Feb. 6	3.24	2		14	3.21	3	33
								8	3.11	2		15	3.33	3	3''.36
1877 April 6	3.54	15		1886 April 10	3.78	8		15	3.50	3	15	20	3.00	1	
7	4.29	11		14	3.35	6		16	3.62	1	3''.31	23	3.13	3	
10	3.69	16		15	3.33	8		18	2.98	2		24	3.68	1	
11	3.44	1		17	3.44	6		20	3.40	2		27	3.07	3	
12	3.99	1	61	18	3.75	6		Mar. 8	3.30	2		30	3.06	4	
15	4.85	2	3''.90	21	3.43	5	50	9	3.54	1		31	3.02	2	
16	3.94	1		23	3.55	5	3''.46								
23	4.12	2		29	3.56	1									
24	4.67	1		30	3.78	1		Mar. 29	3.04	6					
May 4	3.92	9		May 5	2.51	1		April 1	3.50	17		Sept. 1	3.82	2	
6	4.82	2		16	2.67	2		2	3.53	15		7	3.26	1	
				17	2.96	1		3	3.54	3		18	3.77	3	
								5	3.42	13		19	3.30	3	19
May 14	4.09	1		May 25	3.37	2		7	3.49	4		23	2.95	1	3''.55
16	3.99	1		28	3.84	3		10	3.60	1	88	25	3.56	3	
18	4.21	4		30	3.30	3		11	3.74	6	3''.52	28	3.78	3	
28	4.22	1		June 1	3.29	10		12	3.63	6		29	3.47	3	
29	3.66	3		4	2.96	10		16	3.64	1					
30	4.41	1	21	5	3.33	3		18	3.80	11					
31	3.85	2	3''.72												

These values are brought together for convenience of reference, in connection with the weighted mean date of the determination.

	<i>Weighted Mean Date</i>	<i>Latitude</i>	<i>No. Obs.</i>		<i>Weighted Mean Date</i>	<i>Latitude</i>	<i>No. Obs.</i>
1	1876.285	40° 36' 23.65"	56	12	1888.702	40° 36' 23.09"	121
2	76.607	23.56	81	13	89.980	23.10	22
3	77.287	23.90	61	14	90.137	23.31	15
4	77.420	23.72	21	15	90.269	23.52	88
5	77.609	24.24	70	16	90.369	23.62	43
6	77.763	24.09	26	17	90.484	23.57	78
7	78.222	23.51	12	18	90.554	23.55	55
8	85.736	23.72	115	19	90.629	23.36	33
9	86.301	23.46	50	20	90.724	23.55	19
10	86.459	23.32	95	21	90.818	23.15	31
11	86.551	23.86	22	22	90.900	23.05	30

The most noticeable feature of this series is the progressive diminution in the mean value which seems to have taken place, the minimum value in 1876 being apparently nearly the same as the maximum in 1890.

SECOND SERIES.

December 1, 1889, to December 13, 1890.

Before beginning operations on this series the instrument was thoroughly repaired by Saegmüller, of Washington, and a level was selected from some eight or ten which he had in stock and which were regarded as particularly fine tubes. As a result the performance was greatly improved in every way, as may be seen by reference to the probable errors found on page 302.

Level Value.

The level was examined by means of the level-trier five times during the year with the following results:

<i>Date.</i>	<i>Value one division.</i>	<i>Thermometer.</i>	<i>Number determinations.</i>
1889 November 21-23	1.24	46°	5
December 19-21	1.43	42	6
1890 July 14-15	1.16	78	5
November 11-12	1.16	43	4

One determination consists in moving the bubble over the entire length of the scale, or at least considerably more of it than is actually employed in observation, at intervals of two divisions of the micrometer screw, then moving it in the opposite direction at the same readings of the screw. From one to two minutes' time is allowed after each setting for the bubble to come to a condition of equilibrium. About one hour will usually be employed in this operation.

An example follows for illustrating the process and for showing something of the uniformity of the tube.

One division of the screw corresponds to one second of arc in the inclination of the bar.

Thermometer 44.5		Micrometer	Bubble		Mean	Bubble		Mean	Thermometer 44.9
			N	S		N	S		
	1	48	4.5	25.2	14.85	3.7	24.4	14.05	
	2	46	6.0	26.7	16.35	5.6	26.3	15.95	
	3	44	7.4	28.1	17.75	7.5	28.2	17.85	
	4	42	9.5	30.3	19.90	9.4	30.2	19.80	
	5	40	11.4	32.2	21.80	10.8	31.5	21.15	
	6	38	12.9	33.7	23.30	12.4	33.1	22.75	
	7	36	14.5	35.2	24.85	14.4	35.1	24.75	
	8	34	15.7	36.4	26.05	15.5	36.3	25.90	
	9	32	17.9	38.6	28.25	16.9	37.6	27.25	
	10	30	19.2	40.0	29.60	18.4	39.2	28.80	
	11	28	20.8	41.5	31.15	20.1	40.9	30.50	
	12	26	22.4	43.1	32.75	21.9	42.6	32.25	
	13	24	24.0	44.7	34.35	23.1	43.9	33.50	
	14	22	24.9	45.6	35.25	24.6	45.3	34.95	
	15	20	26.7	47.4	37.05	26.2	47.0	36.60	
	16	18	28.0	48.7	38.35	27.5	48.2	37.85	

9—1	13.40	13.20
10—2	13.25	12.85
11—3	13.40	12.65
12—4	12.85	12.45
13—5	12.55	12.35
14—6	11.95	12.20
15—7	12.20	11.85
16—8	12.30	11.95
16'' = 12.74		12.44
One division = 1''.26		1''.29

The large value given in December was a source of perplexity. No satisfactory explanation for it could be found. The six individual values were as follows:

1''.48 1''.47 1''.36 1''.47 1''.36 1''.42

The value employed in reduction of the Latitude observations was 1''.245.

This level was examined about one year after the termination of this series, when it was found to have deteriorated to such an extent as to be practically worthless.

The Micrometer.

The value of one revolution of the micrometer screw was derived from thirty-seven elongations of γ Cephei, 43 Cephei and δ Ursæ Minoris. The details are given in the following table. λ Ursæ Minoris was also observed at a number of elongations, but the results did not harmonize well, either among themselves or with those derived from the

other stars employed. This seems to have been due to the time required for the star to pass over the length of the screw. This was about $1^h 20^m$, the instrument being liable to considerable changes in this interval.

The range of observation was usually twenty-four revolutions, viz.: from scale reading 8 to 32, 20 being regarded as the middle of the field. The correction from progressive error, to be spoken of later, was applied when appreciable.

Assuming the value of one revolution to be $50''.5$, each determination gives an equation of the form

$$R - 50''.5 = x + (T - 45^\circ) y$$

Where R is the observed value of one revolution,

x the correction to the assumed value,

y the temperature coefficient,

T the thermometer reading.

	Date		Star	Elong.	Observed R	Thermom.	$T - 45^\circ$	$R - 50''.5$
1	1889 Dec.	13	51 Cephei	E	50.527	45.5	+ 0.5	+ .027
2	1890 Jan.	14		E	.523	34.8	- 10.2	+ .023
3		27		W	.483	31.9	- 13.1	- .017
4	April	2		W	.529	36.6	- 8.4	+ .029
5		5		W	.488	37.5	- 7.5	- .012
6		18		W	.485	37.0	- 8.0	- .015
7	Oct.	17		E	.501	54.5	+ 9.5	+ .001
8		21		E	.532	44.3	- 0.7	+ .032
9		30		E	.518	38.1	- 6.9	+ .018
10	Nov.	6		E	.508	45.1	+ 0.1	+ .008
11		10	43 Cephei	E	.527	43.0	- 2.0	+ .027
12	Aug.	15		E	.456	68.3	+ 23.6	- .044
13		23		E	.465	67.9	+ 22.9	- .035
14		23		E	.498	55.5	+ 10.5	- .002
15		24		E	.517	54.4	+ 9.4	+ .017
16		24		E	.511	54.4	+ 9.4	+ .011
17		27		E	.485	71.1	+ 26.1	- .015
18		30		E	.489	64.1	+ 19.1	- .011
19	Oct.	30		W	.472	36.0	- 9.0	- .028
20		30		W	.487	35.6	- 9.4	- .013
21		31	δ Ursæ Minoris	W	.485	36.6	- 8.4	- .015
22		31		W	.506	36.6	- 8.4	+ .006
23	Nov.	4		W	.476	32.3	- 12.7	- .024
24		4		W	.498	31.4	- 13.6	- .002
25	1889 Dec.	27		W	.467	41.1	- 3.9	- .033
26		27		E	.508	34.2	- 10.8	+ .008
27		28		W	.462	40.9	- 4.1	- .038
28	1890 Oct.	17		W	.511	56.1	+ 11.1	+ .011
29		17		W	.531	56.1	+ 11.1	+ .031
30		21		W	.531	45.5	+ 0.5	+ .031
31		21		W	.502	44.3	- 0.7	+ .002
32		30		W	.544	41.3	- 3.7	+ .044
33		30		W	.543	37.2	- 7.8	+ .043
34	Nov.	6		W	.491	47.6	+ 2.6	- .009
35		6		W	.473	45.6	+ 0.6	- .027
36		10		W	.530	44.2	- 0.8	+ .030
37		10		W	.522	44.2	- 0.8	+ .022

Giving equal weights to each of the 37 equations, we find in units of the third decimal place

$$x = + 2.15 \pm 2.69$$

$$y = - 0.367 \pm 0.262$$

Therefore

$$R = 50''.50215 - .000367 (T - 45^\circ)$$

This is the value of R employed in the present series of Latitude Observations.

Progressive and Periodic Errors.

Two series of measurements of the screw have been made by means of the measuring engine of the U. S. Naval Observatory, designed by Prof. Harkness for investigating the photographs of the transit of Venus. This was done in February, 1891.

The correction for progressive error was adjusted by a graphic process, no assumption being made as to the law involved. The result is as follows. The first column gives the micrometer reading, the second the correction :

8	+ .0202	21	+ .0002
9	.0182	22	.0014
10	.0162	23	.0031
11	.0141	24	.0052
12	.0121	25	.0067
13	.0100	26	.0081
14	.0080	27	.0096
15	.0046	28	.0111
16	.0019	29	.0126
17	.0000	30	.0140
18	.0000	31	.0155
19	.0001	32	.0170
20	.0002		

If we derive this correction from the transits of the circumpolar stars observed for determining the value of one revolution of the screw, assuming the error to be uniformly progressive we have the following values :

8 and 32	+ .0208	14 and 26	+ .0052
9 31	.0174	15 25	.0036
10 30	.0144	16 24	.0023
11 29	.0117	17 23	.0013
12 28	.0092	18 22	.0006
13 27	.0071	19 21	.0001

The corrections deduced by means of the measuring engine were employed in this reduction.

A series of measurements was also made for the determination of the periodic errors, but the resulting probable error was of the same order of magnitude as the correction; moreover this will be pretty effectually eliminated from the mean of the observations; for these reasons no correction of this kind was applied.

The Reticle.

This was provided with three vertical threads and one horizontal, the latter for marking the middle of the field. As there were no means of making a close adjustment in collimation, the single bisection was made as formerly at the instant when the star crossed the meridian, as shown by the clock, which did not necessarily coincide with the time of crossing the thread. Except, however, in case of the few stars included whose declinations were large, the difference was not important.

The micrometer was fitted with five horizontal threads, the intervals being approximately equal to ten revolutions of the screw. These are numbered consecutively I, II, III, IV and V, a small piece of brass near one end showing the number of each thread for the purpose of avoiding mistakes in identification.

When the difference of zenith distance of the two stars forming a pair was not more than twenty revolutions, both stars were commonly bisected with number III. For greater distances II and IV were employed. I and V were not used.

It was therefore necessary to determine accurately the distance between II and IV, and as this was found to be variable to some extent, the operation must be frequently repeated. Writing $II + x = IV$, the following values of x , in terms of revolutions of the screw, were employed, each being the mean of ten or more determinations:

1889 December 3 —	1890 February 1	$x = .0904 R$
1890 February 1 —	June 1	.0872
June 1 —	August 1	.0842
August 1 —	November 6	.0831
November 6 —	End	.0875

The Star List.

This comprises 111 pairs, 16 of which were found in the old list. Much care was given to the selection of the stars employed, the effort being to include all favorable pairs from 0^h to 24^h which could be observed without overlapping. As ideal pairs were not always to be found, a number were included which were objectionable in one way or another. It was somewhat doubtful whether these should be included in the final discussion, but with the exception of two or three cases no important difference could be discovered between the results from these and the more ideally perfect ones.

Each pair, with two exceptions, was observed both evening and morning. The number of evening observations was 842, of morning 637.

The reduction to apparent declination was carried through twice for each date of observation, once by each of the standard formulæ, viz.:

$$\delta = \delta_0 + \tau\mu' + Aa' + Bb' + Cc' + Dd'$$

and

$$\delta = \delta_0 + \tau\mu' + g \cos (G + a_0) + h \cos (H + a_0) \sin \delta_0 + i \cos \delta_0$$

A, B, C, D, h, H, g, G and i were taken from the American Ephemeris.

The Latitude Observations.

In planning this series of Latitude determinations the effort was made to observe each pair not less than five times, both evening and morning. Practically a few pairs were observed as many as twelve times, and in a few cases the number fell short of five. The evening observations were naturally more numerous than the morning. The usual method was to begin work soon after sundown and to observe from one to three or four hours, then to begin in the morning two hours or more before daylight and to stop only when sunrise ended the operation. Some of the brighter stars were observed with the sun above the horizon.

No attention was given to arranging the pairs in groups to facilitate adjustment. Under these circumstances, in connection with the fact that considerable care has been given to the reduction of the declinations, it is perhaps doubtful whether much will be gained by such an adjustment. The attempt has been made, however, to improve the results in this manner.

For this purpose the series has been divided into ten groups as follows:

Group	I	Right Ascension	h	m		h	m	
			22	20	—	0	27	11 pairs
	II		0	38	—	3	01	10
	III		3	04	—	5	34	11
	IV		5	41	—	7	24	10
	V		7	29	—	9	35	12
	VI		9	47	—	12	36	11
	VII		12	57	—	15	06	11
	VIII		15	17	—	17	24	12
	IX		17	30	—	19	49	11
	X		19	56	—	22	16	12

Reduction to Mean of Groups.

When every pair of a given group has been observed on any night, the mean of the resulting latitudes will be based upon the mean value of the declinations of all stars of

In the tabular statement which follows, the differences of the consecutive values of the latitude are given with the corresponding weight. The latter is computed by the formula

$$p = \frac{nn'}{10(n+n')}$$

n and n' being the number of observations corresponding to the two values of the latitude. When two differences are combined, as in the case of III-IV (Jan. 14-Jan. 20) and (Feb. 22-March 29), the value of p given is the sum of the individual weights. The primed values I-II', etc., refer to the morning series.

			p	$\frac{1}{p}$			p	$\frac{1}{p}$
I- II	—	.026	2.36	.4237	VI- I	+	.017	2.73
II- III	+	.187	1.26	.7937	IV- VI	+	.109	0.34
III- IV	—	.121	1.79	.5587	VIII- II	+	.009	1.07
IV- V	+	.138	1.09	.9174	V-VIII	—	.302	1.80
V- VI	+	.332	1.32	.7576	VIII- III	+	.220	2.48
VI- VII	—	.114	1.22	.8197	VI- IX	—	.112	2.36
VII-VIII	—	.207	2.57	.3891	IX- V	—	.044	2.64
VIII- IX	+	.187	1.49	.6711	VII- IX	+	.039	1.05
IX- X	+	.154	2.42	.4132	X- VI	—	.033	1.07
X- I	—	.043	3.29	.3040	VIII- X	+	.132	2.67
					II-VIII'	—	.101	1.89
I- II'	—	.231	1.17	.8547	III- IX	—	.319	3.73
II- III'	+	.323	1.44	.6944	IX- II	—	.051	2.54
III- IV'	—	.119	1.87	.5348	IV- IX	—	.133	2.85
IV- V'	—	.055	1.73	.5780	X- III	+	.108	1.48
V- VI'	+	.002	.84	1.1905	V- IX'	+	.072	.88
VI- VII'	—	.179	.53	1.8868	X- IV	—	.078	1.51
VII-VIII'	—	.072	1.81	.5525	I- V	—	.066	2.50
VIII- IX'	+	.245	1.07	.9346	VI- X'	+	.107	.92
IX- X'	+	.108	.94	1.0638	II- VI	+	.050	2.51
X- I'	+	.040	2.56	.3906	I- VII	+	.034	2.46

Representing by 1.2; 2.3; 1.2'; 2.3'; the required corrections to the observed differences I-II, II-III, the conditions to be rigorously satisfied are expressed by the 26 equations which follow :

<i>l</i> <i>p</i>	.4237	.7937	.5587	.9174	.7576	.8197	.3891	.6711	.4132	.3040	.8547	.6944	.5348	.5780	1.1905	1.8868	.5525	.9346	1.0638	.3906	.3984
1	1.2	2.3	3.4	4.5	5.6	6.7	7.8	8.9	9.10	10.1											
2	1.2										-1.2'										
3		2.3										-2.3'									
4			3.4										-3.4'								
5				4.5										-4.5'							
6					5.6										-5.6'						
7						6.7										-6.7'					
8							7.8										-7.8'				
9								8.9										-8.9'			
10									9.10										-9.10'		
11										10.1										-10.1'	
12	1.2																				+2.6
13		2.3	+3.4													+6.7'	+7.8'				
14			+3.4	+4.5																	
15																		8.9'			
16					+5.6																
17						6.7													+9.10'		
18							7.8													+10.1'	
19								8.9													
20		2.3																			
21									9.10				+3.4'								
22									9.10					+4.5'							
23										10.1					+5.6'						
24																					
25																					
26																					

Solving these in the usual manner by correlates and employing the weights given above,

	k_1	k_2	k_3	k_4	k_5	k_6	k_7	k_8	k_9	k_{10}	k_{11}	k_{12}	k_{13}
1	6.0482	.4237	.7937	.5587	.9174	.7576	.8197	.3891	.6711	.4132	.3040	.4237	1.3524
2	.4237	1.2784										.4237	
3	.7937		1.4881										.7937
4	.5587			1.0935									.5587
5	.9174				1.4954								
6	.7576					1.9481							
7	.8197						2.7065						—1.8868
8	.3891							.9416					— .5525
9	.6711								1.6057				
10	.4132									1.4770			
11	.3040										.6946		
12	.4237	.4237										1.1884	
13	1.3524		.7937	.5587			— 1.8868	— .5525					7.6675
14	1.4761			.5587	.9174								.5587
15									— .9346				
16	.7576					.7546							
17	.8197						.8197			— 1.0638			
18	.3891							.3891			— .3906		
19	.6711								.6711				
20	.7937		.7937										.7937
21	.4132			— .5348						.4132			
22	.4132				— .5780					.4132			
23	.3040					— 1.1905					.3040		
24													
25													.9346
26													

The solution of these equations gives for k_1, k_2 the values

$$\begin{array}{ll}
 k_1 = + .1744 & k_{14} = - .1370 \\
 k_2 = + .1268 & k_{16} = - .1491 \\
 k_3 = - .0648 & k_{18} = + .0005 \\
 k_4 = - .0400 & k_{17} = - .1052 \\
 k_5 = + .1226 & k_{18} = - .0579 \\
 k_6 = + .1198 & k_{19} = + .1578 \\
 k_7 = + .0089 & k_{20} = - .2325 \\
 k_8 = - .1866 & k_{21} = - .0302 \\
 k_9 = - .2616 & k_{22} = + .0418 \\
 k_{10} = - .0969 & k_{23} = + .0298 \\
 k_{11} = - .2413 & k_{24} = + .0701 \\
 k_{12} = - .0728 & k_{25} = - .1253 \\
 k_{13} = + .0082 & k_{26} = + .0243
 \end{array}$$

k_{14}	k_{15}	k_{16}	k_{17}	k_{18}	k_{19}	k_{20}	k_{21}	k_{22}	k_{23}	k_{24}	k_{25}	k_{26}	
1.4761		.7576	.8197	.3891	.6711	.7937	.4132	.4132	.3040				+ .487
						.7937							+ .205
.5587							— .5348						— .136
.9174								— .5780					— .002
		.7576							— 1.1905				+ .330
			.8197	+ .3891									+ .065
	— .9346		— 1.0638		.6711		.4132	.4132					— .135
				— .3906					.3040				— .058
						.7937					.9346		+ .046
.5587													— .083
2.4349	.5556												+ .041
.5556	1.8690	.3788										.3788	— .067
													— .065
	.3788	1.5601										.3788	— .101
			3.7765										+ .176
				1.5607						.9346			.000
					1.5939	.3937							— .001
					.3937	1.4555					.5291		+ .035
							1.9745	.4132					— .183
							.4132	2.7899				1.1364	+ .010
			.9346						2.9815	1.0870			+ .093
									1.0870	2.0216			+ .002
	.3788	.3788			.5291						1.4637		+ .076
								1.1364				1.5152	— .092
													+ .028

$$\begin{aligned}
1. \ 2 &= .4237 (k_1 + k_2 + k_{12}) &= + .097 \\
2. \ 3 &= .7937 (k_1 + k_3 + k_{13} + k_{20}) &= - .091 \\
3. \ 4 &= .5387 (k_1 + k_4 + k_{13} + k_{14}) &= + .003 \\
4. \ 5 &= .9174 (k_1 + k_5 + k_{14}) &= + .147 \\
5. \ 6 &= .7576 (k_1 + k_6 + k_{16}) &= + .223 \\
6. \ 7 &= .8197 (k_1 + k_7 + k_{17}) &= + .064 \\
7. \ 8 &= .3891 (k_1 + k_8 + k_{18}) &= - .027 \\
8. \ 9 &= .6711 (k_1 + k_9 + k_{19}) &= + .047 \\
9. \ 10 &= .4132 (k_1 + k_{10} + k_{21} + k_{22}) &= + .036 \\
10. \ 1 &= .3040 (k_1 + k_{11} + k_{23}) &= - .011
\end{aligned}$$

$$\begin{aligned}
1. \ 2' &= - .8547 \ k_2 &= - .108 \\
2. \ 3' &= - .6944 \ k_3 &= + .045 \\
3. \ 4' &= - .5348 (k_4 - k_{21}) &= + .005 \\
4. \ 5' &= - .5780 (k_5 - k_{22}) &= - .046 \\
5. \ 6' &= - 1.1905 (k_6 - k_{23}) &= - .107 \\
6. \ 7' &= - 1.8868 (k_7 - k_{13}) &= - .001 \\
7. \ 8' &= - .5525 (k_8 - k_{13}) &= + .108 \\
8. \ 9' &= - .9346 (k_9 - k_{15}) &= + .105 \\
9. \ 10' &= - 1.0638 (k_{10} - k_{17}) &= - .010 \\
10. \ 1' &= - .3906 (k_{11} - k_{18}) &= + .072
\end{aligned}$$

The corrected differences of consecutive groups are now as follows :

I-	II	— .123
II-	III	+ .278
III-	IV	— .124
IV-	V	— .009
V-	VI	+ .109
VI-	VII	— .178
VII-	VIII	— .180
VIII-	IX	+ .140
IX-	X	+ .118
X-	I	— .032
<hr/>		
Σ		— .001

Therefore

I =	II	— .123
	III	+ .155
	IV	+ .031
	V	+ .022
	VI	+ .131
	VII	— .047
	VIII	— .227
	IX	— .087
	X	+ .031

Add to each quantity .0114 in order to make the sum of the corrections zero, we find the following series of values, which are applied to the latitudes derived from the different groups to reduce all to a homogeneous system.

I	+ .01
II	— .11
III	+ .17
IV	+ .04
V	+ .03
VI	+ .14
VII	— .04
VIII	— .21
IX	— .07
X	+ .04

This system of corrections, together with those given on page 310, being applied to the individual determinations of latitude, we obtain the results given on the folding sheet, where will be found in detail the definitive latitude as given by each observation of the entire series.



Daily Mean of Latitude.

	P.M.	No.	A.M.	No.		P.M.	No.	A.M.	No.		P.M.	No.	A.M.	No.
1889 Dec.	1 3.05	17			1890 April	11 3.79	5	3.86	9	1890 Aug.	9 2.94	7		
	2 3.20	4				12 3.54	8	3.56	9		10		3.42	6
	4 3.32	9				16 3.93	7				14 3.21	3	3.13	12
	6 2.85	16				18 3.89	8	3.81	3		15 3.32	8		
	7 2.98	16	3.25	7		21 3.83	6				20 3.30	6		
	9 2.92	10	3.23	7		25 3.31	3				23 2.95	8	2.98	11
	11 2.87	19	2.96	9		28 3.66	6	3.32	2		24 3.42	6		
			3.28	6		30 3.41	5	3.23	4		27 3.08	5	3.26	9
			3.08	6	May	2 3.86	3				30 3.18	6	3.15	11
			3.40	11		5 3.44	6				31		3.17	13
			2.56	1		8 3.34	4	3.67	6	Sept.	1 3.49	8	3.13	7
1890 Jan.	14 3.09	4				11 3.86	5				2		3.39	9
	17 3.11	5				12 3.73	6				7 3.26	6		
			3.21	12		15		3.45	7		18 3.46	11	3.14	8
			3.10	2		16 3.63	5				19 3.10	11		
			3.16	9		17		3.64	9		21		3.67	5
			3.21	9		20		3.50	2		22		3.30	9
Feb.	5 3.23	12				21 3.72	5				23 2.68	5	2.99	11
	6 3.49	11	3.27	12		22 3.52	7	3.16	7		25 3.27	8		
	8		3.30	12		27		3.43	7		28 3.37	10	3.07	10
	9 3.43	6				28		3.46	6		29 3.10	10		
	10 3.35	14			June	31 3.30	5			Oct.	4		3.09	13
	12 3.38	15				1 3.46	7				8 3.34	10	3.28	10
			3.30	9		3 3.40	7				14 2.82	9	3.01	14
			3.44	5		8 3.64	8				15 2.99	11		
			3.13	6		14		3.48	4		17		3.30	11
			3.35	7		15		3.32	9		21 3.06	10	3.13	11
	22 3.47	6				18		3.54	7		30		3.16	12
Mar.	26 3.19	8				19 3.28	6	3.57	6		31 3.12	10	3.14	9
	6 3.54	8				20 3.50	6			Nov.	1 3.10	13		
	7 3.50	8				25 3.59	12	3.51	9		4		3.19	13
	8 3.64	10	3.25	7		26 3.32	10	3.38	7		5		3.20	16
			3.45	5		27 3.36	6				13 3.00	15	3.09	12
	17 3.38	2				29 3.13	12	3.54	8		14 2.95	16		
	18 3.35	8			July	30 3.12	10	3.84	6		21 3.19	17		
	23 3.34	3				5 3.67	12	3.63	7		22 3.12	19	3.09	4
	24 3.55	2				6 3.49	4	3.36	7		24 2.91	17		
	28 3.54	4				18 3.22	4	3.48	9		25		3.13	1
	29 3.12	8				19 3.56	8	3.45	2		27		3.32	6
April	1 3.68	6	3.68	5		20 3.79	8	3.41	11		28 3.07	15	2.94	3
	2 3.61	7	3.31	7		21		3.42	9		29 2.90	15		
	3 3.64	3				22 3.05	8	3.53	8		30 3.04	11		
	4 3.53	4				30 3.08	3			Dec.	3		3.32	5
	5 3.54	11	3.49	9		31 3.07	7	2.86	1		10		2.65	4
	7 3.39	3	3.62	4	Aug.	3 3.44	5				12 2.86	6	3.15	7
	10 3.60	4	3.39	3		6 3.46	7	3.30	9		13 2.79	6	3.21	5

Final Values of Latitude.

Weighted Mean Date.	ϕ P.M.	No.	ϕ A.M.	No.	Mean.	A.M.-P.M.
1889 December 11	3.015	103	3.194	47	3.104	+ .179
1890 February 4	3.345	72	3.231	56	3.288	- .114
March 1	3.451	50	3.312	39	3.382	- .139
April 4	3.518	60	3.578	37	3.548	+ .060
April 23	3.651	56	3.541	24	3.596	- .110
May 22	3.566	47	3.442	38	3.504	- .124
June 26	3.408	86	3.507	70	3.458	+ .099
July 26	3.312	57	3.415	55	3.364	+ .103
August 25	3.250	50	3.168	72	3.209	- .082
September 22	3.213	61	3.183	43	3.198	- .030
October 19	3.074	63	3.151	80	3.112	+ .077
November 16	3.036	84	3.158	46	3.097	+ .122
December 3	2.959	53	3.137	30	3.048	+ .178

The probable error of a single determination computed from the daily mean of all, and therefore including that part due to the declinations employed, is found to be as follows :

Evening observations	0.222
Morning observations	0.246

The Constant of Aberration.

As each pair of stars, with two exceptions, was observed both evening and morning, when the effect of aberration was not far from its maximum value, this series is well adapted to an investigation of that constant, if by any means the effect of the latitude variation can be eliminated. In fact this formed a part of the original plan in arranging the scheme of observation.

Unfortunately, however, in a series like this, the effect of aberration cannot be separated from the latitude variation without some assumption with regard to one or the other. In the present case it has been assumed that the latter can be represented by a single periodic function, the period being fourteen months. Each observation will then give an equation of the form

$$\phi_0 + \Delta + Ax + By + C\rho + T\mu = \phi$$

Where ϕ_0 is an assumed latitude,
 Δ a constant correction,
 $Ax + By$ the periodic terms,
 $C\rho$ the correction on account of error in Struve's aberration constant,
 $T\mu$ uniformly progressive change in the latitude.

For full details as to the process of combining and solving these equations, reference may be had to the series of 1892-93.

The resulting correction to Struve's value of the constant of aberration, which is the only term we are now concerned with, is

	+ '' .0027 \pm 0140
Struve's value	20'' .4451
Final result	20'' .448 \pm 014

It is no doubt an open question whether this value is entitled to very great confidence as a determination of the aberration constant. If the series had been continued for three months longer, so as to embrace an entire period of fourteen months, or if it had happened to be arranged symmetrically with respect to a maximum and minimum value of the latitude, its weight would no doubt have been very materially increased.

As neither of these conditions have been met, it appears quite doubtful whether the method pursued has been entirely successful in eliminating the latitude variation.

At all events it has not been thought advisable to introduce any correction on account of aberration. The foregoing results therefore, as to latitude, depend upon Struve's value of this constant.

THIRD SERIES.

October 10, 1892, to December 27, 1893.

Before beginning this series some changes were made in the building and instrument, the most important being the following:

The width of the observing slit was increased from 20 to 36 inches. It was hoped that this might reduce the liability to disturbance in the way of irregular refraction. The instrument was fitted with two latitude levels to replace the single one before used. The latter had deteriorated to such an extent as to be worthless for refined determination of latitude. The new levels were furnished by G. Saegmüller, of Washington, and proved superior to any heretofore employed.

The Level Values.

The method of determining these, with an example illustrating the process, will be found in the publication of results for 1894, '95.* That series being a continuation of this one, no change in this particular occurred.

Six different determinations were made as follows. The upper level is called *A*, the lower *B*:

1892	September 30–October	1	<i>A</i> 1.335	<i>B</i> 1.006	Thermom. 62
	December 29–December	31	1.395	1.058	24
1893	March 30–March	31	1.370	1.024	44
	June 25–June	26	1.175	0.995	67
	October 4–October	12	1.307	1.044	59
1894	January 7–January	8	1.273	1.037	36

The values employed are as follows:

1892	October	–1893	February	<i>A</i> 1.365	<i>B</i> 1.032
1893	March	–	June	1.272	1.010
	July	–	October	1.238	1.020
	November	–	December	1.286	1.040

In observing care was taken to keep the level correction small, in order to minimize the effect of any uncertainty as to the true value.

* Vol. xx, TRANSACTIONS OF THE AMERICAN PHILOSOPHICAL SOCIETY, Article iii.

The Micrometer.

The description of the micrometer and reticle found in the publication of results for 1894, '95, before referred to, applies equally to the present series. The methods of observing and of determining the intervals of the micrometer threads being the same in both series.

At various times transits of circumpolar stars near elongation were observed for the purpose of determining the screw value. Of these 51 Cephei and δ Ursæ Minoris were each observed at five elongations; 43 Cephei at twenty, and Groombridge 750 at fifteen elongations respectively. In comparing the results it became obvious that the effect of constant use in wearing the screw was manifest, and that the value should be treated as a variable quantity.

The method of procedure adopted, as seeming least objectionable, was to derive the screw value from the latitude observations, as will be explained presently.

The above-mentioned transits of circumpolar stars were employed for investigating the progressive errors, which were increasing with the increased wearing of the screw.

Let n be the number of revolutions of the screw reckoned from the middle of the scale—the middle in this case is revolution 20.

R the mean value of one revolution.

The errors being supposed uniformly progressive, the space s corresponding to n will have the form

$$S = Rn + \rho n^2$$

For a second reading

$$\begin{aligned} S' &= Rn' + \rho n'^2 \\ S - S' &= R(n - n') + \rho(n^2 - n'^2) \end{aligned}$$

The transits are observed from 33 to 7. The observed times are corrected for change of level and curvature of the stars' path. They are then combined by subtracting 33 from 19, 32 from 18, 21 from 7, thus obtaining a series of values for the time required for the star to pass over a space equal to fourteen revolutions of the screw. If no progressive or other errors were present these times should be equal. The difference between any individual value and the mean of all is taken as the correction due to the progressive error expressed in seconds of time. This must then be reduced to the equivalent in screw revolutions.

In the following tabular statement is found the mean values of these differences, those for 51 Cephei being reduced to the scale of δ Ursæ Minoris and those for 43 Cephei to Groombridge 750.

	Micrometer	$n^2 - n'^2$	Observed dif.	$\frac{v}{\sigma - \sigma}$	
1	19 — 33	— 168	— 3.64	+ .53	51 Cephei and δ Ursæ Minoris.
2	18 — 32	— 140	— 2.29	— .30	
3	17 — 31	— 112	— 2.23	+ .16	
4	16 — 30	— 84	— 1.04	— .51	
5	15 — 29	— 56	— 1.24	+ .20	
6	14 — 28	— 28	— .67	+ .15	
7	13 — 27	— 0	+ .36	— .36	
8	12 — 26	+ 28	+ .88	— .36	
9	11 — 25	+ 56	+ .94	+ .10	
10	10 — 24	+ 84	+ 1.82	— .27	
11	9 — 23	+ 112	+ 2.29	— .22	
12	8 — 22	+ 140	+ 2.41	+ .18	
13	7 — 21	+ 168	+ 2.36	+ .75	
1	19 — 33	— 168	— 1.70	— .13	43 Cephei and Groombridge 750.
2	17 — 31	— 112	— 1.34	+ .12	
3	15 — 29	— 56	— .71	+ .10	
4	13 — 27	— 0	+ .20	— .20	
5	11 — 25	+ 56	+ .51	+ .10	
6	9 — 23	+ 112	+ 1.22	— .00	
7	7 — 21	+ 168	+ 1.82	+ .01	

The “observed difference” is the observed value of $\rho (n^2 - n'^2)$.

The time required for 51 Cephei to pass over a space equal to one revolution is $57^s.06$.

That for 750 Groombridge $40^s.92$. Therefore,

From 51 Cephei and δ Ursæ Minoris $\rho = + .01855 = + .000325 R$

43 Cephei and 750 Groombridge $+ .01086 = + .000265 R$

Mean $+ .000295 R$

Which is the value employed in this series.

The corresponding corrections in terms of screw revolutions follow:

7 and 33	+ .0499
8 32	.0425
9 31	.0357
10 30	.0295
11 29	.0239
12 28	.0189
13 27	.0145
14 26	.0106
15 25	.0074
16 24	.0047
17 23	.0027
18 22	.0012
19 21	.0003

A preliminary reduction of the latitude observations is now carried out, applying

these corrections to the micrometer readings and using an approximate value of the screw. The temperature coefficient deduced from the 1889, '90 series has been used. This was derived before the complication due to wearing of the screw had become noticeable and seemed reliable. The value assumed is as follows:

$$R = 50''.5194 - .000367 [T - 45^\circ]$$

T being the thermometer reading.

Each latitude determination now gives an equation of the form

$$\sqrt{p} [\Delta\phi - (M - M') \Delta\frac{1}{2}R = n]$$

Where $\Delta\phi$ and ΔR are the corrections to the assumed latitude and micrometer values respectively. An example illustrating this process may be found in the published results for 1894, '95, before referred to.

Sixteen series of equations were formed for determining the values of $\Delta\phi$ and $\Delta\frac{1}{2}R$, the time embraced by each series therefore averages something less than a month.

The results for $\Delta\frac{1}{2}R$ follow. No use was made of $\Delta\phi$:

					$\Delta\frac{1}{2}R$	<i>Adjusted</i> $\Delta\frac{1}{2}R$	<i>c-o</i>
1	1892	October	10-October	24	— .0111	— .0088	+ 23
2		October	30-November	26	— .0090	— .0056	+ 34
3		December	1-December	23	+ .0029	— .0024	— 53
4		December	26-January	20	+ .0017	+ .0009	— 08
5	1893	January	21-February	16	— .0001	+ .0041	+ 42
6		February	20-March	18	+ .0100	+ .0073	— 27
7		March	18-April	4	+ .0131	+ .0106	— 25
8		April	16-May	7	+ .0124	+ .0138	+ 14
9		May	8-June	8	+ .0209	+ .0170	— 39
10		June	8-June	30	+ .0216	+ .0203	— 13
11		July	2-July	23	+ .0205	+ .0242	+ 37
12		July	27-August	10	+ .0244	+ .0288	+ 44
13		September	2-September	23	+ .0336	+ .0337	+ 01
14		September	27-October	24	+ .0366	+ .0381	+ 15
15		October	25-November	30	+ .0461	+ .0425	— 36
16		December	4-December	27	+ .0484	+ .0470	— 14

The adjustment was graphic and, as will be seen, the increase in $\Delta\frac{1}{2}R$ differs but little from the linear form.

The micrometer frame carried five threads numbered consecutively. The respective distances were made as nearly as possible equal to ten revolutions of the screw. In observing a latitude pair the bisection was made with thread III, unless the difference of

zenith distance was as great as twenty revolutions. In such cases threads II and IV were used to avoid the large number of turns of the screw.

The distance between II and IV was therefore required with accuracy and was determined at frequent intervals. Below will be found the amount to be added to the micrometer correction required on account of the amount by which II-IV differed from twenty revolutions. The progressive diminution is evidently due mainly to the increased value of R from wearing:

1892	October	10	+ 1.54	1893	February	24	+ 0.83
	October	14-November 17	+ 1.25		"	25	+ 0.82
	November	20	+ 1.20		February	26-July 21	+ 0.81
	"	22	+ 1.16		July	23	+ 0.77
	"	26	+ 1.11		"	27-August 10	+ 0.74
	December	1-December 11	+ 1.05		September	2-September 22	+ 0.55
	"	2	+ 1.01		"	23	+ 0.48
	"	12	+ 0.97		"	27-October 24	+ 0.42
	"	15	+ 0.94		October	25	+ 0.36
	"	17	+ 0.90		"	28	+ 0.31
	December	18-February 15	+ 0.86		October	29-November 16	+ 0.25
1893	February	16	+ 0.85		November	26	+ 0.16
	"	20	+ 0.84		"	28-December 25	+ 0.06

The Star List.

The list of stars found in the following pages shows the values of the coordinates for 1892, '93 actually employed in the latitude reduction. The Right Ascensions differ slightly from the definitive values, but this is of no importance for present purposes. The last column, headed "correction for curvature," is the only one which appears to call for explanation. This is the sum of the values of the quantity

$$\frac{1}{4} (15 T)^2 \sin 1'' \tan \delta$$

Computed for each star of the pair, T being the interval from the time of bisection to the time of passing the meridian.

The reduction to apparent place was made by the formula

$$\frac{1}{2} (\delta + \delta') = \frac{1}{2} (\delta_0 + \delta'_0) + \frac{1}{2} (\mu' + \mu_1') \tau + \frac{1}{2} (a' + a_1') A + \frac{1}{2} (b' + b_1') B + \frac{1}{2} (c' + c_1') C + \frac{1}{2} (d' + d_1') D$$

A , B , C and D being taken from the American Ephemeris.

Group	No.	B.A.C.	$\alpha 1892$	$\alpha 1893$	$\delta 1892$	$\delta 1893$	μ'	Cor. for Curvature
I	1	6599	h m s 19 12 37.11	s 39.19	° ' '' 37 56 29.82	'' 36.09	'' + .0140	'' + .06
		6656	19 20 31.77	33.66	43 10 39.27	46.13	— .0362	
	2	6697	19 26 58.91	60.43	51 29 59.15	66.71	+ .1250	+ .06
		6740	19 35 6.55	8.92	29 54 16.46	24.59	+ .0468	
	3	6784	19 42 19.52	21.80	33 28 35.54	43.76	— .4397	+ .06
		6830	19 48 56.15	57.91	47 39 11.19	20.36	— .0070	
	4	6876	19 55 56.84	58.72	45 28 39.28	48.98	— .0197	+ .06
		6915	20 2 20.99	23.21	35 40 30.41	40.19	— .4269	
	5	6962	20 9 54.36	56.24	46 29 20.22	30.97	— .0141	+ .06
		6998	20 14 30.25	32.55	34 38 43.57	54.69	+ .0108	
II	1	7037	20 19 37.34	37.64	68 32 5.31	16.82	+ .0330	+ .09
		7094	20 28 50.50	53.33	12 39 26.94	39.10	+ .0388	
	7	7140	20 33 41.82	44.50	20 49 20.54	33.01	+ .0112	+ .07
		7176	20 38 0.22	1.50	60 6 52.81	65.73	+ .1673	
	8	7213	20 43 12.08	14.42	36 5 38.18	51.29	+ .0026	+ .06
		7254	20 49 32.09	34.19	44 46 21.49	35.00	— .0053	
	9	7297	20 55 47.26	49.53	39 49 52.35	66.47	+ .2072	+ .06
		7326	20 59 49.46	51.70	41 12 4.03	18.15	— .0476	
	10	7380	21 10 25.51	28.51	4 48 5.56	20.29	— .0764	+ .13
		7438	21 16 52.56	52.00	76 33 26.80	41.99	+ .0105	
II	1	7509	21 28 55.90	55.70	75 55 43.89	59.74	— .0107	+ .13
		7522	21 33 7.28	10.29	5 17 4.32	20.42	+ .0308	
	2	7561	21 38 52.92	55.86	9 22 47.99	64.37	+ .0093	+ .10
		7597	21 41 44.91	45.66	71 49 30.18	46.65	— .0433	
	3	BD 59.2444	21 55 55.16	57.05	59 46 48.32	65.51	+ .0044	+ .07
		7712	22 2 46.01	48.83	21 10 38.09	55.51	— .0655	
	4	7760	22 8 10.99	12.38	69 35 56.13	73.85	+ .0075	+ .10
		7796	22 16 12.09	15.04	11 39 40.03	58.08	+ .0166	
	5	7820	22 20 8.05	10.47	48 55 43.77	61.94	— .0133	+ .06
		7843	22 25 5.39	8.13	32 1 11.56	29.91	— .0058	
II	6	7915	22 36 38.55	41.23	39 39 40.80	59.54	— .0029	+ .05
		7932	22 39 16.47	19.14	41 15 9.05	27.88	+ .0148	
	7	7962	22 45 29.46	32.16	41 22 53.38	72.37	— .0061	+ .05
		7978	22 48 15.14	17.88	39 35 36.42	55.48	— .0121	
	8	8024	22 56 56.72	59.25	56 31 31.05	50.34	— .0064	+ .07
		8052	23 1 51.11	54.03	24 53 7.44	26.82	— .0279	
	9	8078	23 6 17.05	20.09	8 8 1.20	20.71	+ .0139	+ .12
		8122	23 13 59.14	61.32	73 5 55.02	74.64	— .0321	

Group	No.	B.A.C.	$\alpha 1892$	$\alpha 1893$	$\delta 1892$	$\delta 1893$	μ'	Cor. for Curvature
III	1	8195 8229	^h 23 ^m 25 ^s 58.63 23 32 50.27	^s 61.57 53.20	[°] 38 ['] 38 ["] 34.70 42 40 12.61	["] 54.46 32.53	["] — .0731 + .0026	["] + .06
	2	8252 8284	23 37 49.95 23 44 11.40	52.85 14.43	52 33 12.23 28 14 28.17	32.18 48.20	— .0042 + .0194	+ .07
	3	8317 8324	23 50 8.99 23 52 15.33	11.97 18.38	56 48 39.88 24 32 27.64	59.91 47.65	— .0108 — .0258	+ .07
	4	16 LL 220	0 4 42.50 0 11 5.32	45.60 8.44	45 28 16.31 35 53 22.91	36.35 42.98	— .0054 + .0501	+ .06
	5	99 126	0 22 21.14 0 26 51.69	24.25 55.06	18 55 0.51 62 20 8.36	20.46 28.27	— .0090 — .0050	+ .07
	6	194 222	0 38 30.94 0 43 4.70	34.80 7.81	74 23 51.48 6 59 49.90	71.22 69.57	— .0307 — .0349	+ .13
	7	259 318	0 50 45.48 1 1 48.74	48.79 52.11	37 54 48.37 43 21 59.45	67.97 78.72	+ .0380 — .0602	+ .06
	8	394 413	1 13 52.52 1 18 2.58	56.47 5.79	64 5 29.61 17 15 19.22	48.60 38.09	— .0293 — .0307	+ .08
	9	438 459	1 23 11.69 1 26 49.53	16.07 52.70	69 42 30.97 11 19 36.81	49.64 55.45	— .0748 + .0061	+ .10
	10	480 502	1 30 27.54 1 34 12.29	31.04 15.81	40 51 54.15 40 1 47.50	72.29 65.86	— .3709 — .0217	+ .05
IV	1	592 611	1 51 26.96 1 55 0.62	30.23 4.97	17 17 24.20 63 52 5.06	41.91 22.64	— .0171 + .0010	+ .08
	2	656 706	2 3 7.04 2 12 18.73	10.60 22.58	34 28 34.28 46 52 52.50	51.47 69.28	— .0355 — .0143	+ .06
	3	744 780	2 20 9.88 2 26 59.28	14.74 62.58	66 54 59.22 14 33 21.82	75.64 37.92	+ .0074 + .0402	+ .09
	4	816 872	2 35 19.25 2 43 37.57	23.51 41.06	54 38 40.29 26 48 54.19	55.88 69.24	— .0286 — .1028	+ .06
	5	916 963	2 52 41.97 3 1 8.46	45.84 12.35	40 36 7.48 40 32 20.98	22.06 35.09	— .0405 + .0045	+ .05
	6	981 993	3 4 19.01 3 7 46.58	22.86 50.54	39 12 3.23 42 5 59.41	17.15 73.12	+ .0083 + .0164	+ .06
	7	1050 1068	3 19 7.72 3 21 18.96	13.83 22.21	71 29 12.68 9 21 20.54	25.63 33.31	+ .0046 — .0366	+ .10
	8	1119 1144	3 33 19.21 3 39 38.08	22.60 43.51	16 11 5.84 65 11 28.97	17.78 40.48	— .0304 — .0130	+ .08
	9	1221 1237	3 50 29.11 3 55 27.20	32.65 32.17	23 9 59.06 58 51 17.12	69.69 27.49	— .1052 — .0006	+ .07
	10	1274 1286	4 2 52.42 4 7 22.56	55.89 27.81	19 19 23.33 61 34 40.44	33.10 49.89	— .0842 — .0136	+ .07

Group	No.	B. A. C.	$\alpha 1892$	$\alpha 1893$	$\delta 1892$	$\delta 1893$	μ'	Cor. for Curvature
V	1	1307	^h ^m ^s 4 11 6.79	^s 11.28	[°] ['] ^{''} 49 47 5.09	^{''} 14.19	^{''} — .0623	^{''} + .06
		1364	4 19 13.64	17.44	31 11 40.53	48.95	— .1161	
	2	1425	4 31 24.38	29.08	52 51 49.02	56.56	— .0166	+ .06
		1444	4 34 34.07	37.82	28 24 18.46	25.73	— .0298	
	3	1486	4 43 58.01	61.86	6 46 20.17	26.73	+ .0845	+ .13
		1496	4 48 38.09	45.64	74 6 3.77	9.94	+ .0298	
	4	1536	4 53 48.72	54.04	60 17 0.84	6.53	— .0140	+ .07
		1555	4 57 55.41	58.98	21 7 33.24	38.61	— .0156	
	5	1583	5 3 28.20	33.76	62 33 25.88	30.78	+ .0079	+ .08
		1625	5 10 25.17	28.68	18 19 6.68	10.98	— .0040	
VI	1	2045	6 17 23.08	28.32	58 28 31.30	29.77	— .0072	+ .07
		2101	6 23 50.59	54.22	22 36 58.11	56.03	+ .0021	
	2	2139	6 29 7.32	11.45	38 31 55.12	52.55	— .0215	+ .06
		2159	6 31 37.08	41.87	42 34 59.54	56.72	— .0594	
	3	2187	6 36 41.49	46.80	59 32 60.42	57.21	— .0037	+ .07
		2233	6 45 4.71	8.31	21 53 16.82	12.87	— .0298	
	4	2301	6 56 38.42	42.23	29 30 63.76	58.04	— .8112	+ .06
		2341	7 4 58.07	62.77	51 36 25.36	19.75	+ .0048	
	5	2365	7 9 16.43	21.63	59 6 33.96	27.96	— .0243	+ .07
		2410	7 13 40.40	43.98	22 10 50.49	44.15	— .0056	
	6	2429	7 19 38.58	44.88	68 41 7.27	0.39	— .0479	+ .69
		2473	7 23 47.11	50.45	12 13 45.77	38.58	— .0099	
	7	2488	7 28 41.21	45.58	46 25 4.24	56.67	— .0091	+ .06
		2509	7 32 6.98	10.91	34 49 52.83	44.85	— .1296	
	8	2551	7 37 55.68	59.30	24 39 23.26	14.89	— .0515	+ .07
		2616	7 47 41.48	46.38	56 47 15.51	6.40	— .0231	
	9	2676	7 57 27.90	31.44	22 22 22.99	13.15	+ .0018	+ .07
		2704	8 1 12.06	17.02	58 33 49.44	39.24	— .0786	
	10	2786	8 13 30.36	34.02	27 33 61.13	49.72	— .3769	+ .06
		2792	8 15 37.89	42.44	53 33 61.09	49.80	— .0999	
	11	2819	8 21 17.52	22.55	61 4 43.03	31.32	— .1155	+ .07
		2880	8 29 6.95	10.40	17 57 40.05	27.90	— .0000	
	12	2953	8 38 32.92	36.32	18 32 63.20	50.17	— .2303	+ .07
		2982	8 44 23.52	33.52	62 21 56.76	43.59	+ .0237	

Group	No.	B.A.C.	$\alpha 1892$	$\alpha 1893$	$\delta 1892$	$\delta 1893$	μ'	Cor. for Curvature
VII	1	3003 3052	^{h m s} 8 47 21.66 8 51 33.31	^s 26.87 36.66	^{° ' "} 65 0 59.45 15 59 44.39	["] 45.98 30.78	["] — .0886 + .0371	["] + .08
	2	3083 3109	8 57 42.81 9 1 31.02	47.06 34.64	51 14 73.52 30 5 17.00	59.40 2.73	— .0793 + .0062	+ .06
	3	3140 3170	9 8 24.95 9 12 56.43	29.30 59.95	54 27 63.03 26 42 23.87	48.40 8.90	+ .0646 — .0167	+ .06
	4	3228 3231	9 22 44.10 9 24 41.72	47.29 47.49	8 39 33.31 72 40 64.52	17.79 48.82	— .0093 — .0743	+ .11
	5	3281 3307	9 31 37.20 9 35 18.87	40.96 22.60	40 43 27.75 40 14 59.27	11.76 43.04	+ .0113 — .0402	+ .05
	6	3375 3397	9 47 10.62 9 51 8.04	14.21 11.85	35 29 31.01 45 55 42.80	14.23 25.79	— .0030 — .0440	+ .06
	7	3468 3505	10 4 48.70 10 10 34.96	52.27 38.60	37 55 61.21 43 26 72.44	43.60 54.59	— .0340 — .0372	+ .06
	8	3530 3584	10 15 45.41 10 23 48.23	48.99 51.75	41 46 38.74 39 28 39.79	20.58 21.48	— .1403 + .0024	+ .05
	9	3647 3693	10 34 34.61 10 40 42.05	38.76 45.24	66 16 55.04 14 45 53.32	36.29 34.40	— .0752 — .0516	+ .09
	10	3725 3751	10 47 2.00 10 50 42.75	5.66 46.01	55 9 32.62 26 4 36.19	13.57 17.04	— .0186 — .0090	+ .06
VIII	1	3787 3825	10 59 29.74 11 6 27.39	32.94 30.92	25 46 70.21 55 28 51.77	50.79 32.25	— .0596 — .0097	+ .06
	2	3877 3914	11 18 17.62 11 24 59.24	20.75 62.86	11 7 26.63 69 55 37.48	6.83 17.64	— .0734 — .0239	+ .10
	3	3949 LL 22186	11 32 2.45 11 38 28.65	5.73 31.79	51 12 59.99 30 10 46.23	40.05 26.29	— .0348 + .0166	+ .06
	4	4010 W.B. 956	11 46 45.40 11 50 47.81	48.88 50.93	38 29 36.80 42 36 52.84	11.01 32.79	—5.7721 — .0091	+ .05
	5	4074 4099	12 0 12.31 12 5 1.35	15.38 4.41	63 31 71.28 17 24 37.09	51.15 17.05	— .0818 + .0070	+ .08
	6	4123 4141	12 10 4.89 12 13 51.93	7.88 54.97	57 37 57.70 23 37 64.65	37.67 44.63	+ .0024 — .0108	+ .07
	7	4195 4217	12 21 33.29 12 24 56.58	36.28 59.44	28 51 67.68 52 7 53.87	47.64 33.94	— .0803 + .0032	+ .06
	8	4239 4271	12 28 52.41 12 36 25.13	55.00 28.16	70 22 60.87 10 49 50.92	40.93 31.02	+ .0069 — .0969	+ .10
	9	4300 4318	12 42 42.11 12 46 50.06	44.69 53.04	63 21 74.17 17 39 41.16	54.45 21.52	— .0102 — .0043	+ .08
	10	4371 4403	12 57 34.17 13 4 29.33	36.56 32.28	64 11 25.35 17 25 29.05	5.94 9.79	+ .0109 + .0011	+ .08
	11	4433 4467	13 8 49.16 13 15 28.61	51.89 31.30	40 43 29.10 40 42 63.06	9.96 44.07	+ .0093 — .0135	+ .05

Group	No.	B.A.C.	$\alpha 1892$	$\alpha 1893$	$\delta 1892$	$\delta 1893$	μ'	Cor. for Curvature
IX	1	4510	^h ^m ^s 13 24 29.23	^s 31.44	[°] ['] ^{''} 60 29 72.98	^{''} 54.30	^{''} + .0240	^{''} + .07
		4562	13 35 30.91	33.77	20 29 67.51	49.20	+ .0277	
	2	4694	14 1 38.79	41.44	31 21 57.84	40.45	— .0994	+ .06
		4701	14 4 15.20	17.45	49 57 66.69	49.57	+ .0504	
	3	4728	14 10 2.28	4.71	42 1 33.37	16.36	— .1011	+ .06
		4758	14 15 21.60	24.07	39 17 25.80	9.15	— .0024	
	4	4825	14 30 13.64	16.10	37 5 61.91	45.96	— .0536	+ .06
		4841	14 34 9.18	11.44	44 6 29.04	13.39	+ .0293	
	5	4874	14 39 21.71	23.20	61 43 20.20	4.77	— .0323	+ .07
		4905	14 46 24.51	27.26	19 32 57.37	42.29	— .0803	
	6	4926	14 51 7.40	10.23	14 52 58.86	44.14	— .0009	+ .09
		4949	14 55 52.14	53.09	66 21 45.20	30.79	+ .0170	
	7	4974	15 0 13.80	15.78	48 4 30.32	16.19	+ .0361	+ .06
		5000	15 6 16.30	18.72	33 29 17.10	3.32	— .0023	
X	1	5072	15 17 29.11	31.51	33 19 13.36	0.31	+ .0104	+ .06
		5113	15 25 57.02	58.93	48 4 63.10	50.61	— .0050	
	2	5147	15 29 24.74	25.57	64 34 19.26	7.10	+ .0806	+ .08
		5180	15 36 1.11	3.86	16 22 23.64	11.85	— .0093	
	3	5210	15 39 54.69	56.34	52 41 66.78	55.31	+ .0352	+ .06
		5236	15 44 7.40	9.87	28 29 17.86	6.65	+ .0011	
	4	5271	15 48 56.38	58.45	42 45 14.01	3.79	+ .6288	+ .07
		5295	15 51 51.84	54.02	38 15 32.77	22.22	+ .0844	
	5	BD72.703	15 56 44.08	43.46	72 41 62.83	52.58	+ .0179	+ .11
		5366	16 3 15.61	18.50	8 49 18.19	8.42	— .0015	
	6	5466	16 17 9.33	11.98	19 24 25.18	16.52	+ .0463	+ .07
		5512	16 22 31.87	32.68	61 45 31.30	23.08	+ .0554	
	7	5568	16 33 2.08	3.83	46 49 55.35	47.93	+ .0082	+ .06
		5619	16 39 52.82	55.04	34 14 17.25	10.46	+ .0709	
	8	5658	16 44 38.54	39.78	55 35 64.75	58.27	— .0066	+ .06
		5703	16 50 36.89	39.35	25 54 18.03	12.04	— .0109	
	9	5752	16 57 22.74	23.84	56 50 49.64	44.26	+ .0306	+ .07
		5786	17 4 5.61	8.08	24 37 39.16	34.28	— .0421	
	10	5842	17 13 20.06	22.27	33 12 59.99	55.94	+ .0035	+ .06
		5911	17 23 52.40	53.99	48 20 62.87	59.71	— .0149	

Group	No.	B.A.C.	α1892	α1893	δ1892	δ1893	μ'	Cor. for Curvature
XI	1	5941	h m s 17 29 55.26	s 58.05	° ' '' 12 38 20.16	'' 17.31	— .2256	+ .10
		6006	17 37 35.10	34.74	68 48 28.08	26.44	+ .3151	
	2	6122	17 57 3.41	2.37	72 0 54.91	54.64	— .0078	+ .11
		6143	18 2 13.74	16.58	9 32 55.88	56.18	+ .0969	
	3	6193	18 9 28.61	30.61	38 44 36.44	37.28	+ .0043	+ .06
		6203	18 12 17.07	18.92	42 7 21.62	22.70	+ .0024	
	4	6232	18 15 42.19	44.51	29 37 10.65	12.03	+ .0102	+ .06
		6258	18 18 57.06	58.47	51 14 55.90	57.54	— .0122	
	5	6300	18 25 7.06	9.55	23 47 40.74	42.95	+ .0137	+ .07
		6348	18 30 42.63	43.66	56 57 46.84	49.51	— .0137	
	6	6373	18 37 5.70	6.42	60 36 38.58	41.86	+ .0451	+ .07
		6387	18 41 0.90	3.48	20 26 35.68	38.91	— .3341	
	7	6476	18 51 56.27	57.85	48 43 27.97	32.35	— .1240	+ .06
		6491	18 54 54.24	56.48	82 32 29.85	34.61	+ .0029	
	8	6534	19 0 50.89	53.17	31 34 59.88	65.07	— .0706	+ .06
		6579	19 9 17.51	19.08	49 39 8.10	14.69	+ .6214	

The Latitude Observations.

The details of the latitude determination are given in the pages following. The expression for the latitude is as follows :

$$\phi = \frac{1}{2}(\delta + \delta') + \frac{1}{2}R(M - M') + \frac{1}{4}d[(n - n') - (s' - s)] + (m + m') + \frac{1}{2}(r - r')$$

M and M' are the micrometer readings.

n, s, n', s' , the readings of the north and south ends of the levels for the two stars.

m and m' , the correction for curvature.

r and r' , the corrections for refraction.

The columns which seem to call for explanation are as follows :

Column P gives the position of the instrument.

D , Direct. The telescope east when pointed south of the zenith.

R , Reverse. The telescope west when pointed south of the zenith.

C , The correction on account of progressive errors of the screw.

Levels A and B , the value of $(n - n') - (s' - s)$ for each level.

Column δ gives the sum of the corrections for $\Delta \frac{1}{2}R$ given on page 322 with that for curvature found in the last column of the star list.

In case of those pairs observed with threads II and IV the correction given on page 323 is included.

Column Δ gives the reduction on account of the adopted value of the Constant of Aberration, to be explained later.

Throughout this table the footnote references *a*, *b*, *c* and *d* indicate as follows: *a* = e. e. f.; *b* = definition very poor; *c* = levels discordant; *d* = clouds.

1892	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	δ'	r			
Oct. 10	I	4 D	18.4877	22.1190	+ 6	+ .9	— .6	40 34 51.52	+ 1 31.73	+ 3	+ 8	+ 3	40 36 23.39	+ 9	54.2
			20.0707	20.9057	+ 3	— .4	+ .8	40 36 2.20	+ 21.10	+ 8	+ 3	+ 1	23.42	+ 8	
			32.6067 ^{iv}	8.7467 ⁱⁱ	+ 16	+ 1.1	+ .6	40 26 18.72	+ 10 2.70	+ 1.39	+ 26	+ 17	23.24	+ 9	53.6
			14.7310	25.8190	+ 16	+ .2	+ .3	40 41 2.85	— 4 40.10	+ 23	+ 7	— 12	22.93	+ 7	
			22.1520	21.4243	+ 9	— 1.1	— 2.0	40 36 41.56	+ 18.40	+ 14	— 45	— 1	22.84	+ 7	
	V	4 D	29.6377	15.4283	+ 211	— .4	— 1.3	40 42 23.42	— 5 59.47	+ 20	— 24	— 11	23.80	— 2	41.6
			7.5773 ⁱⁱ	31.3813 ^{iv}	— 15	— 1.1	— 2.7	40 26 22.10	+ 10 1.26	+ 1.41	— 54	+ 20	24.43	— 2	
			21.6360	22.5233	+ 11	— 1.6	— 1.2	40 36 45.48	— 22.44	+ 14	— 43	— 1	22.74	— 2	
			28.0750 ^{iv}	13.3790 ⁱⁱ	+ 63	— .5	— .4	40 42 35.83	— 6 11.39	— 1.33	— 13	— 13	22.85	— 2	
			22.2050	18.5667	+ 9	— 2.0	— 1.0	40 34 26.13	+ 1 57.18	+ 4	— 47	+ 4	22.92	— 3	
	VI	4	28.5293	14.6763	+ 131	+ 1.7	+ 2.4	40 42 12.48	— 5 50.27	+ 18	+ 60	— 10	22.89	— 3	
			18.6760	21.8100	+ 5	— 1.0	— 1.8	40 37 42.44	— 1 19.18	+ 10	— 40	— 3	22.93	— 3	
			15.4673	24.0997	— 12	— 1.1	— 2.2	40 32 45.46	+ 3 38.02	— 1	— 47	+ 7	23.07	— 3	
			26.8063	10.8113	— 113	— 1.4	— 2.8	40 43 8.08	— 6 43.75	+ 21	— 60	— 13	23.81	— 3	43.0
			23.6200	17.2347	+ 15	— 1.3	— 1.4	40 33 42.31	+ 2 41.33	— 0	— 40	+ 5	23.29	— 3	43.0
Oct. 11	I	1 D	8.0673 ⁱⁱ	29.3600 ^{iv}	— 9	— 1.2	— 1.4	40 27 24.03	+ 8 57.83	+ 1.44	— 38	+ 19	23.11	— 3	42.1
			24.4047	18.3080	+ 49	+ .1	— .2	40 33 49.21	+ 2 34.10	+ 1	— 1	+ 4	23.35	+ 9	60.3
			27.3083	13.0777	+ 17	+ .1	— .7	40 42 23.07	— 5 59.47	+ 19	— 7	— 10	23.62	+ 9	
			25.4633	20.1743	+ 87	— .7	— .6	40 34 9.34	+ 2 13.80	+ 1	— 19	+ 4	23.00	+ 9	60.3
			18.3310	21.9413	+ 2	+ 1.3	+ 1.8	40 34 51.60	+ 1 31.19	+ 3	+ 45	+ 3	23.30	+ 9	60.3
			19.1520	24.0420	+ 44	+ 1.8	+ 2.3	40 34 19.43	+ 2 3.62	+ 2	+ 60	+ 3	23.70	+ 9	
			19.6553	20.4610	— 1	— .1	+ .1	40 36 2.29	+ 20.35	+ 8	0	+ 1	22.73	+ 8	
			30.9173 ^{iv}	12.0160 ⁱⁱ	— 9	— .6	— 1.4	40 28 24.37	+ 7 57.37	+ 1.15	— 28	+ 15	22.76	+ 8	
			32.1103 ^{iv}	8.2270 ⁱⁱ	+ 3	— 1.2	— 1.0	40 26 18.85	+ 10 3.23	+ 1.10	— 33	+ 17	23.02	+ 9	58.5
			28.4277	16.3310	+ 168	— 1.1	— .2	40 31 17.76	+ 5 5.94	— 5	— 21	+ 8	23.52	+ 9	
	II	1	21.7453	21.0433	+ 6	— 1.8	— 2.6	40 36 41.72	— 17.75	+ 14	— 64	— 1	23.46	+ 7	57.2
			19.5307	19.7467	0	+ 2.1	+ 2.6	40 36 27.53	— 5.46	+ 10	+ 69	0	22.86	+ 7	
			14.0190	31.4287	+ 280	— .9	— 2.0	40 29 03.56	+ 7 20.42	— 8	— 41	+ 14	23.63	+ 8	
			36.2087 ^{iv}	12.4557 ⁱⁱ	+ 95	— 1.6	— 2.9	40 26 22.19	+ 10 0.21	+ 1.12	— 65	+ 20	23.07	— 2	49.0
			21.9283	21.0837	+ 7	— 3.6	— 3.6	40 36 45.54	— 21.38	+ 14	— 1.08	— 1	23.21	— 2	
	V	5 R	14.9223	29.6697	+ 198	— 1.8	— 1.0	40 42 35.89	— 6 13.01	+ 21	— 43	— 13	22.53	— 2	
			21.5097	26.1500	+ 105	— 2.7	— 1.8	40 34 26.16	+ 1 57.48	+ 4	— 69	+ 4	23.03	— 3	
			14.2300	28.0500	+ 92	— 1.5	— 1.8	40 42 12.51	— 5 49.31	+ 18	— 31	— 10	22.97	— 3	48.9
			22.3943	19.2800	+ 16	— .7	— 1.0	40 37 42.46	— 1 18.71	+ 10	— 25	— 3	23.57	— 3	
			26.7120	18.0737	+ 122	— 1.7	— 2.2	40 32 45.46	+ 3 38.50	— 1	— 57	+ 7	23.45	— 3	
Oct. 14	I	3	14.4247	30.4120	+ 238	— 2.6	— .6	40 43 8.05	— 6 44.40	+ 21	— 52	— 13	23.21	— 3	
			17.9813	24.3747	+ 46	— .7	— 1.0	40 33 42.26	+ 2 41.61	— 0	— 25	+ 5	23.67	— 3	
			15.1283	29.3763	+ 190	— 1.4	— 1.4	40 42 23.05	— 6 0.33	+ 19	— 43	— 10	22.39	+ 9	64.4
			19.5710	24.8563	+ 68	+ .5	— 1.1	40 34 9.38	+ 2 13.66	+ 1	— 5	+ 4	23.04	+ 9	
			24.0647	20.4537	+ 49	— .5	— 1.0	40 34 51.68	+ 1 31.32	+ 3	— 21	+ 3	22.85	+ 9	63.5
			23.8753	18.9813	+ 42	— .1	+ .3	40 34 19.56	+ 2 3.71	+ 2	+ 3	+ 3	23.35	+ 9	
			20.6190	19.7977	+ 1	— 1.0	— 1.5	40 36 2.46	+ 20.75	+ 8	— 36	+ 1	22.94	+ 8	62.6
			12.6413 ⁱⁱ	31.5407 ^{iv}	— 17	+ .1	— .5	40 28 24.58	+ 7 57.29	+ 1.15	— 5	+ 15	23.12	+ 9	
			10.9820 ⁱⁱ	34.8677 ^{iv}	+ 68	— .1	— 1.7	40 26 19.11	+ 10 3.43	+ 1.10	— 23	+ 17	23.58	+ 9	
			15.0763	27.1530	+ 80	+ .4	+ 1.4	40 31 18.06	+ 5 5.22	— 5	+ 25	+ 8	23.56	+ 9	
	II	10	28.1250	17.0760	+ 169	— .4	— 1.0	40 41 3.32	— 4 39.48	+ 23	— 20	— 12	23.75	+ 7	61.9
			23.7493	24.4720	+ 19	— 3.2	— 3.5	40 36 42.08	— 18.30	+ 14	— 99	— 1	22.92	+ 7	
			22.0410	21.8627	+ 2	— 1.3	— 1.7	40 36 27.94	— 4.51	+ 10	— 44	0	23.09	+ 7	
			30.8350	13.4327	+ 219	— 2.7	— 3.6	40 29 4.05	+ 7 20.07	— 8	— 92	+ 14	23.26	+ 8	60.2
			14.2197	30.5180	+ 226	— 5.3	— 7.6	40 29 32.45	+ 6 52.24	— 8	— 1.88	+ 12	22.85	— 1	51.2
	V	1 D	30.8323 ^{iv}	6.9977 ⁱⁱ	— 24	— .5	— 1.2	40 26 19 92	+ 10 1.96	+ 1.17	— 24	+ 24	23.05	— 1	
			27.4323	13.1690	+ 26	+ .4	+ .3	40 42 23.91	— 6 0.33	+ 20	+ 11	— 11	23.78	— 2	
			20.7950	21.6730	+ 8	— 3.6	— 4.2	40 36 45.81	— 22.20	+ 14	— 1.15	— 1	22.59	— 2	51.3
			27.7513	12.9723	+ 34	+ .5	— .2	40 42 36.14	— 6 13.38	+ 21	+ 6	— 13	22.90	— 2	
			21.6333	16.9660	— 19	— 1.5	— 2.6	40 34 26.37	+ 1 57.84	+ 4	— 59	+ 4	23.70	— 3	

1892	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Oct. 14	V 9		27.9637	14.1773	+ 87	-1.7	-3.1	40 42 12.69	+ 5 48.44	+ 18	- 69	-10	23.64	-3	50.6
	VI 1		17.7610	26.3807	+105	-1.0	-1.9	40 32 45.56	+ 3 37.99	- 1	- 41	+ 7	23.20	-3	50.6
	2		24.7813	17.7893	+ 54	- .7	-1.5	40 33 27.18	+ 2 56.74	- 0	- 31	+ 5	23.66	-3	
	3		29.6873	13.7040	+160	- .7	-2.0	40 43 8.07	+ 6 44.12	+ 21	- 38	-13	23.65	-3	
	4		24.1997	17.8227	+ 38	- .5	-1.5	40 33 42.19	+ 2 41.17	- 0	- 28	+ 5	23.13	-3	50.1
Oct. 16	6		10.2540 ^{II}	31.5587 ^{IV}	+ 7	-1.2	-2.0	40 27 23.83	+ 8 58.15	+1.15	- 46	+19	22.86	-3	50.0
	7		22.3697	19.9860	+ 17	-2.2	-2.5	40 37 24.48	- 1 0.25	+ 8	- 70	- 2	23.59	-3	
	V 1	R	30.5960	14.4027	+239	+1.9	+2.0	40 29 32.77	+ 6 49.62	- 8	+ 58	+12	23.01	-1	54.9
	2		20.1663	24.5160	+ 60	+1.6	+1.6	40 38 12.43	- 1 50.01	+ 10	- 48	- 3	22.97	-1	
	3		12.9690 ^{II}	36.7973 ^{IV}	+110	- .2	- .4	40 26 20.16	+10 2.13	+1.17	- 8	+24	23.62	-1	53.5
	4		14.9007	29.1540	+170	-1.3	-1.3	40 42 24.16	- 6 0.44	+ 20	- 39	-11	23.42	-2	
	5		31.7520 ^{IV}	8.0120 ^{II}	- 2	-2.8	-1.7	40 26 22.77	+ 9 59.62	+1.12	- 69	+20	23.02	-2	
	6		23.4453	22.5627	+ 17	-1.4	-1.6	40 36 45.99	- 22.34	+ 14	- 44	- 1	23.34	-2	
	7		15.3547	30.0787	+236	-1.2	-3.0	40 42 36.31	- 6 12.50	+ 21	- 59	-13	23.30	-2	
	8		19.8340	24.4710	+ 60	- .8	-1.7	40 34 26.51	+ 1 57.27	+ 4	- 35	+ 4	23.51	-2	
Oct. 19	9		14.4910	28.2893	+114	-2.2	-2.8	40 42 12.84	- 5 48.81	+ 18	- 73	-10	23.38	-2	52.0
	10		23.7823	20.6587	+ 41	-1.4	- .9	40 37 42.71	- 1 19.00	+ 10	- 35	- 3	23.43	-3	
	VI 1		25.7637	17.1567	+ 73	-2.1	- .3	40 32 45.65	+ 3 37.58	- 1	- 40	+ 7	22.89	-3	
	2		18.7787	25.7830	+ 95	-1.8	-2.4	40 33 27.25	+ 2 57.16	- 0	- 61	+ 5	23.85	-3	
	3		14.0270	30.0167	+191	-1.8	-1.6	40 43 8.12	- 6 44.36	+ 21	- 51	-13	23.33	-3	52.3
	4		17.4323	23.8193	+ 22	-1.0	-1.8	40 33 42.20	+ 2 41.38	- 0	- 40	+ 5	23.23	-3	
	5		17.8507	23.2523	+ 18	-2.2	- .9	40 38 39.66	- 2 16.48	+ 12	- 49	- 4	22.77	-3	
	6		31.4320 ^{IV}	10.1017 ^{II}	+ 6	-1.9	-2.0	40 27 23.79	+ 8 58.78	+1.15	- 58	+19	23.33	-3	
	7		20.8750	23.2430	+ 29	-2.7	-2.8	40 37 24.42	- 59.89	+ 8	- 82	- 2	23.77	-3	
	8		31.5090	15.2487	+325	- .9	-1.5	40 43 14.72	- 6 51.53	+ 21	- 35	-12	22.93	-3	a
Oct. 19	I 1	D	25.2527	19.1507	+ 79	-1.5	- .3	40 33 48.82	+ 2 34.32	+ 1	- 29	+ 4	22.90	+9	61.9
	2		27.1397	12.8927	0	+ .1	- .2	40 42 22.83	- 5 59.84	+ 19	- 1	-10	23.07	+9	
	3		23.3527	18.0270	+ 22	-1.3	-1.1	40 34 9.23	+ 2 14.57	+ 1	- 36	+ 4	23.49	+9	
	4		19.9467	23.5903	+ 39	- .9	-1.9	40 34 51.61	+ 1 32.12	+ 3	- 40	+ 3	23.39	+9	59.6
	5		19.2847	24.1827	+ 51	+ .6	+ .3	40 34 19.56	+ 2 3.84	+ 2	+ 14	+ 3	23.59	+9	
	6		21.4503	22.2717	+ 10	- .3	-1.1	40 36 2.51	+ 20.77	+ 8	- 19	+ 1	23.18	+8	
	7		30.2387 ^{IV}	11.3223 ^{II}	- 4	+ .7	- .4	40 28 24.71	+ 7 57.76	+1.15	+ 7	+15	23.84	+9	
	8		33.3223 ^{IV}	9.4750 ^{II}	+ 31	-2.7	- .8	40 26 19.29	+10 2.35	+1.10	- 56	+17	22.35	+9	
	9		26.5483	14.4500	+ 36	- .5	- .2	40 31 18.30	+ 5 5.66	- 5	- 11	+ 8	23.88	+9	58.1
	10		14.4533	25.5583	0	-1.9	-1.7	40 41 3.59	- 4 40.48	+ 23	- 54	-12	22.68	+7	
Oct. 19	II 1		20.2490	19.5080	0	+ .3	+ .1	40 36 42.41	- 18.72	+ 14	+ 6	- 1	23.88	+7	56.9
	2		18.8923	19.0880	0	-2.1	-3.0	40 36 28.32	- 4.94	+ 10	- 74	0	22.74	+7	
	3		13.3703	30.7267	+210	- .8	-2.3	40 29 4.53	+ 7 18.91	- 8	- 43	+14	23.07	+8	55.6
	V 1	D	13.3740	29.6053	+143	- .6	-1.7	40 29 33.13	+ 6 50.35	- 8	- 32	+12	23.20	-1	48.8
	2		22.8940	18.5400	+ 18	+ .9	+ .1	40 38 12.75	- 1 50.03	+ 10	+ 17	- 3	22.96	-1	
	3		31.4503 ^{IV}	7.6190 ^{II}	- 11	-3.2	-2.9	40 26 20.40	+10 1.93	+1.17	- 92	+24	22.82	-1	
	4		28.0190	13.7230	+ 73	- .6	-1.5	40 42 24.42	- 6 1.29	+ 20	- 29	-11	22.93	-2	
	5		7.9283 ^{II}	31.6563 ^{IV}	- 5	- .5	-2.3	40 26 22.99	+ 9 59.84	+1.12	- 38	+20	23.27	-2	
	6		20.0030	20.9320	+ 3	-1.9	-1.9	40 36 46.15	- 23.47	+ 14	- 57	- 1	22.24	-2	
	7		26.9567	12.1743	- 38	+ .9	- .8	40 42 36.47	- 6 13.29	+ 21	+ 5	-13	23.31	-2	
Oct. 19	8		22.0423	17.4090	- 9	-3.4	-3.0	40 34 26.62	+ 1 57.01	+ 4	- 96	+ 4	22.75	-2	
	9		28.5730	14.7220	+136	- .1	0	40 42 12.95	- 5 50.21	+ 18	- 1	-10	22.81	-2	
	10		18.4567	21.6153	+ 1	-3.5	-3.2	40 37 42.79	- 1 19.79	+ 10	-1.01	- 3	22.06	-2	
	VI 1		16.2407	24.8793	+ 29	-1.4	-3.4	40 32 45.69	+ 3 38.28	- 1	- 68	+ 7	23.35	-3	
	2		25.3940	18.3873	+ 78	-2.4	-3.3	40 33 27.26	+ 2 57.18	- 0	- 83	+ 5	23.66	-3	
	3		29.7073	13.7137	+160	-1.9	-1.1	40 43 8.11	- 6 44.39	+ 21	- 46	-13	23.34	-3	46.3
	4		24.3440	17.9637	+ 44	-1.3	-2.2	40 33 42.10	+ 2 41.28	- 0	- 50	+ 5	22.93	-3	
	5		22.2727	17.9027	+ 2	- .8	-2.2	40 38 39.56	- 2 15.65	+ 12	- 42	- 4	23.57	-3	
	6		8.6413 ^{II}	29.9437 ^{IV}	- 6	- .9	-1.8	40 27 23.66	+ 8 58.07	+1.15	- 38	+19	22.69	-3	
	7		20.9770	18.5927	- 3	- .3	-1.4	40 37 24.25	- 1 0.22	+ 8	- 23	- 2	23.86	-4	

1892	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections.				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Oct. 19	VI	8	12.9573	29.2467	+105	0	— .1	40 43 14.51	— 6 51.72	+ 21	— 1	—12	40 36 22.87	—3	46.3
Oct. 21	I	9	29.6150 ^{iv}	9.7393 ⁱⁱ	0	—1.7	—3.5	40 28 0.50	+ 8 22.04	+1.14	— 74	+16	23.10	—3	44.7
		1	18.9013	25.0020	+ 70	+ .4	+ .2	40 33 48.77	+ 2 34.27	+ 1	+ 9	+ 4	23.18	+9	56.9
		2	14.6940	28.8910	+151	—2.8	—3.5	40 42 22.80	— 5 58.97	+ 19	— 93	—10	22.99	+9	
		3	19.1830	24.5107	+ 59	+ .4	— .7	40 34 9.23	+ 2 14.72	+ 1	— 2	+ 4	23.98	+9	55.4
		4	23.1043	19.4567	+ 27	—2.2	—2.4	40 34 51.63	+ 1 32.20	+ 3	— 68	+ 3	23.21	+9	
		5	24.3007	19.3673	+ 53	—2.8	—3.7	40 34 19.61	+ 2 4.74	+ 2	— 95	+ 3	23.45	+9	
		6	24.3480	23.5130	+ 19	— .8	—1.5	40 36 2.58	+ 21.14	+ 8	— 33	+ 1	23.48	+9	53.6
		8	9.0550 ⁱⁱ	32.9323 ^{iv}	+ 22	— .5	—1.3	40 26 19.41	+10 3.15	+1.10	— 25	+17	23.58	+9	52.4
		9	16.7263	28.8047	+196	— .1	—1.6	40 31 18.44	+ 5 5.57	— 5	— 22	+ 8	23.82	+9	
		10	28.6770	17.6000	+206	0	—1.5	40 41 3.75	— 4 40.30	+ 23	— 19	—12	23.37	+7	52.4
	II	1	21.5627	22.2903	+ 8	—2.9	—3.3	40 36 42.58	— 18.40	+ 14	— 92	— 1	23.39	+7	
		2	21.8040	21.6080	0	—1.2	—1.9	40 36 28.52	— 4.95	+ 10	— 45	0	23.22	+7	51.7
		3	30.4873	13.1200	+185	—2.2	—1.5	40 29 4.86	+ 7 19.13	— 8	— 57	+14	23.48	+8	50.9
	V	1	29.8907	13.6753	+170	—1.5	—1.6	40 29 33.33	+ 6 50.04	— 8	— 46	+12	22.95	—1	44.1
		2	19.9930	24.3413	+ 55	+1.0	0	40 38 12.92	— 1 49.98	+ 10	+ 17	— 3	23.18	—1	
		3	11.0537 ⁱⁱ	34.8760 ^{iv}	+ 67	— 3	—1.8	40 26 20.50	+10 1.92	+1.17	— 28	+24	23.55	—1	
		4	14.9957	29.2703	+180	—2.5	—1.3	40 42 24.55	— 6 1.04	+ 20	— 59	—11	23.01	—1	
		5	33.1123 ^{iv}	9.3827 ⁱⁱ	+ 27	— .5	— .2	40 26 23.09	+ 9 59.48	+1.12	— 11	+20	23.78	—2	43.1
		6	24.0117	23.1193	+ 18	— .3	—1.7	40 36 46.20	— 22.59	+ 14	— 27	— 1	23.47	—2	
		7	15.5940	30.3433	+258	—2.6	—2.1	40 42 36.52	— 6 13.22	+ 21	— 71	—13	22.67	—2	
		8	20.2270	24.8107	+ 68	+ .3	— .2	40 34 26.64	+ 1 55.95	+ 4	+ 2	+ 4	22.69	—2	
		9	13.5760	27.4210	+ 42	— .8	+ .2	40 42 12.96	— 5 49.84	+ 18	— 11	—10	23.09	—2	
		10	23.5457	20.4450	+ 37	—1.0	—3.2	40 37 42.77	— 1 18.42	+ 10	— 58	— 3	23.84	—2	43.0
	VI	1	25.2653	16.6300	+ 47	—4.5	—2.8	40 32 45.65	+ 3 38.24	— 1	—1.12	+ 7	22.83	—3	42.4
		2	19.7730	26.7563	+134	+ .3	+ .1	40 33 27.20	+ 2 56.73	— 0	+ 6	+ 5	24.04	—3	
		3	14.6383	30.5923	+245	—4.1	—3.3	40 43 8.03	— 6 43.62	+ 21	—1.12	—13	23.37	—3	
		4	17.2597	23.6670	+ 17	—1.0	—1.3	40 33 41.98	+ 2 41.89	— 0	— 34	+ 5	23.58	—3	41.8
		5	19.1980	24.5553	+ 59	—3.5	—2.6	40 38 39.42	— 2 15.47	+ 12	— 93	— 4	23.10	—3	a
		6	34.6177 ^{iv}	13.2980 ⁱⁱ	+ 30	—2.4	—1.6	40 27 23.51	+ 8 58.62	+1.15	— 61	+19	22.86	—3	
		7	19.4417	21.8277	+ 8	—1.6	— .3	40 37 24.07	— 1 0.29	+ 8	— 31	— 2	23.53	—4	
		8	30.8533	14.6220	+262	+ .7	—1.1	40 43 14.30	— 6 50.67	+ 21	— 2	—12	23.70	—4	42.6
		9	12.2993 ⁱⁱ	32.1687 ^{iv}	0	+ .1	+ .3	40 28 0.26	+ 8 21.91	+1.14	+ 5	+16	23.52	—3	42.5
Oct. 23	I	1	25.0083	18.9210	+ 74	+1.1	+1.7	40 33 48.72	+ 2 33.94	+ 1	+ 41	+ 4	23.12	+9	55.0a
		2	27.1413	12.8933	0	+ .4	+2.3	40 42 22.79	— 5 59.88	+ 19	+ 36	—10	23.36	+9	
		3	24.0290	18.7517	+ 42	+1.5	+2.7	40 34 9.25	+ 2 13.40	+ 1	+ 60	+ 4	23.30	+9	
		4	17.9353	21.5477	— 7	+2.2	+3.0	40 34 51.68	+ 1 31.23	+ 3	+ 76	+ 3	23.73	+9	
		5	18.5767	23.4780	+ 31	+ .6	+1.0	40 34 19.69	+ 2 3.87	+ 2	+ 23	+ 3	23.84	+9	
		8	33.0250 ^{iv}	9.1660 ⁱⁱ	+ 24	— .6	— .3	40 26 19.54	+10 2.69	+1.10	— 14	+17	23.36	+9	52.9
		9	27.9260	15.8713	+135	— .6	— .3	40 31 18.62	+ 5 4.79	— 5	— 14	+ 8	23.30	+9	
	II	1	20.6193	19.8503	0	+ .1	— .4	40 36 42.80	— 19.42	+ 14	— 3	— 1	23.48	+7	
		2	20.5323	20.7503	0	—2.2	—2.1	40 36 28.76	— 5.51	+ 10	— 64	0	22.71	+7	
		3	13.1227	30.4800	+185	—1.2	—1.8	40 29 5.03	+ 7 18.88	— 8	— 43	+14	23.54	+8	51.3
	V	1	12.5303	28.7220	+ 57	+1.9	+ .9	40 29 33.56	+ 6 49.14	— 8	+ 44	+12	23.18	0	45.6
		2	20.7237	16.3733	— 37	—1.0	—1.3	40 38 13.11	— 1 49.80	+ 10	— 34	— 3	23.04	—1	
		3	31.2983 ^{iv}	7.4963 ⁱⁱ	— 15	— .5	— .8	40 26 20.64	+10 1.19	+1.17	— 19	+24	23.05	—1	45.5
		4	26.3777	12.0910	— 65	—1.7	—1.7	40 42 24.69	— 6 0.71	+ 20	— 51	—11	23.56	—1	
		5	8.0880 ⁱⁱ	31.8173 ^{iv}	— 1	+1.8	0	40 26 23.21	+ 9 59.39	+1.12	— 30	+20	23.62	—2	
Oct. 24	I	6	20.1630	21.0987	+ 4	—2.9	—1.6	40 36 46.26	— 23.65	+ 14	— 70	— 1	22.04	—2	45.4
		2	14.5427	28.7530	+137	—2.4	—2.1	40 42 22.77	— 5 59.29	+ 19	— 68	—10	22.89	+9	47.1
		3	19.8007	25.1057	+ 76	— .1	— .6	40 34 9.25	+ 2 14.19	+ 1	— 9	+ 4	23.40	+9	
		4	26.5597	22.9373	+101	+ .3	— .7	40 34 51.70	+ 1 31.76	+ 3	— 4	+ 3	23.48	+9	
		5	24.0010	19.0987	+ 44	—1.7	—1.9	40 34 19.72	+ 2 3.94	+ 2	— 53	+ 3	23.18	+9	46.1
Oct. 30	I	6	24.9517	24.1530	+ 20	0	+ .1	40 36 2.73	+ 20.23	+ 8	+ 1	+ 1	23.06	+8	45.2
		5	18.1607	23.0460	+ 18	— .3	— .2	40 34 19.51	+ 2 3.45	+ 3	— 7	+ 3	22.95	+9	47.7

1892	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections.				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Oct. 30	6		18.5357	19.3257	— 5	+ .7	+1.6	40 36 2.63	+ 19.94	+ 9	+ 32	+ 1	22.99	+ 8	
			32.0200 ^{iv}	13.1583 ⁱⁱ	— 20	— .2	— .4	40 28 24.98	+ 7 56.39	+1.22	— 8	+15	22.66	+ 8	
			33.8360 ^{iv}	10.0163 ⁱⁱ	+ 43	+ .1	+ .2	40 26 19.66	+10 1.79	+1.18	+ 4	+17	22.84	+ 9	
			27.3353	15.2983	+ 92	+ .7	— .2	40 31 18.81	+ 5 4.28	— 1	+ 9	+ 8	23.25	+ 9	
			14.4323	25.5983	0	— .1	+ .5	40 41 4.30	— 4 42.05	+ 19	+ 5	—12	22.37	+ 7	45.6
	II		22.4637	21.6620	+ 10	—1.9	— .8	40 36 43.24	— 20.27	+ 13	— 43	— 1	22.66	+ 7	45.1
			19.2777	19.5237	0	— .2	+ .9	40 36 29.28	— 6.21	+ 10	+ 8	0	23.25	+ 7	
			13.2400	30.5687	+195	— .4	—1.0	40 29 5.69	+ 7 18.21	— 2	— 20	+14	23.82	+ 8	
			22.6017	18.3653	+ 13	—1.9	—3.5	40 38 9.96	— 1 47.04	+ 12	— 77	— 4	22.23	+ 7	43.5
			33.2243 ^{iv}	11.9460 ⁱⁱ	+ 4	— .6	—1.4	40 27 49.48	+ 8 32.23	+1.19	— 28	+14	22.76	+ 8	
Nov. 5	V	D	12.9587 ⁱⁱ	28.9220 ^{iv}	— 22	—2.2	—3.3	40 29 39.64	+ 6 43.17	+1.21	— 80	+12	23.34	+ 8	
			29.3240	14.2807	+158	+ .3	— .4	40 42 43.66	— 6 20.39	+ 15	0	—11	23.31	+ 8	
			18.2493	20.5157	— 8	—1.2	—2.4	40 37 20.78	— 57.23	+ 13	— 51	— 2	23.15	+ 6	42.3
			19.4443	20.4150	+ 2	—1.0	—1.4	40 36 46.90	— 24.52	+ 14	— 35	— 1	22.16	— 1	39.2
			27.5480	12.7307	+ 13	—1.5	—2.6	40 42 37.20	— 6 14.33	+ 16	— 59	—13	22.31	— 2	
	VI		29.9267	16.1323	+246	—1.0	—1.2	40 42 13.49	— 5 49 08	+ 14	— 32	—10	24.13	— 2	
			20.4410	23.5983	+ 38	+ .7	— .3	40 37 43.17	— 1 19 85	+ 9	+ 8	— 3	23.46	— 2	39.2
			15.4953	24.1277	— 10	— .9	—1.7	40 32 45.93	+ 3 38.04	+ 2	— 37	+ 7	23.69	— 3	
			24.9207	17.9310	+ 57	—2.5	—3.1	40 33 27.39	+ 2 56.71	+ 2	— 82	+ 5	23.35	— 3	
			28.4627	12.4567	+ 43	— .4	—1.6	40 43 8.11	— 6 44.44	+ 16	— 27	—13	23.43	— 3	
			23.2653	17.8913	+ 18	—1.2	—1.7	40 33 41.82	+ 2 41.06	+ 2	— 42	+ 5	22.53	— 3	37.6
			24.3283	18.9580	+ 52	—1.9	—2.9	40 38 39.17	— 2 15.79	+ 10	— 70	— 4	22.74	— 3	α
			10.2803 ⁱⁱ	31.6173 ^{iv}	+ 7	+ .2	— .4	40 27 23.16	+ 8 59.01	+1.22	— 1	+19	23.57	— 3	37.5
			12.4813	28.7427	+ 59	—1.6	—1.0	40 43 13.70	— 6 50.93	+ 16	— 40	—12	22.41	— 4	
			31.4900 ^{iv}	11.5943 ⁱⁱ	0	—1.0	—1.2	40 27 59.50	+ 8 22.59	+1.21	— 32	+16	23.14	— 4	36.3
	VII	R	24.0840	18.1707	+ 40	— .4	— .3	40 33 52.94	+ 2 29.48	+ 3	— 11	+ 4	22.38	— 4	
			14.3693	27.0563	+ 54	—1.5	—3.0	40 31 3.13	+ 5 20.63	— 0	— 64	+10	23.22	— 4	
			30.4850	8.9913	— 31	—1.7	—1.8	40 27 20.56	+ 9 2.88	— 5	— 52	+17	23.04	— 4	35.9
			25.6013	16.8433	+ 63	+ .4	— .6	40 40 4.32	— 3 41.39	+ 11	0	— 7	22.97	— 4	35.9 α
			24.8843	20.0173	+ 70	+1.4	+1.6	40 34 19.26	+ 2 3.12	+ 3	+ 44	+ 3	22.88	+ 9	
Nov. 8	II		23.2530	22.4567	+ 14	+ .1	+1.5	40 36 2.50	+ 20.15	+ 9	+ 21	+ 1	22.96	+ 8	34.2
			11.9987 ⁱⁱ	30.8263 ^{iv}	— 9	+2.7	+3.2	40 28 24.91	+ 7 55.60	+1.22	+ 87	+15	22.75	+ 8	
			10.8767 ⁱⁱ	34.7077 ^{iv}	+ 61	+2.1	+1.1	40 26 19.64	+10 2.17	+1.18	+ 50	+17	23.66	+ 9	
			16.2880	28.3073	+163	+2.0	+2.4	40 31 18.85	+ 5 4.05	— 1	+ 65	+ 8	23.62	+ 9	32.9
			22.6030	22.2733	+ 5	+5.6	+6.0	40 36 29.58	— 8.34	+ 10	+1.73	0	23.07	+ 7	32.6
	I	D	31.2757	14.0193	+272	+ .6	+1.5	40 29 6.06	+ 7 16.62	— 2	+ 30	+14	23.10	+ 8	32.6
			30.6520 ^{iv}	12.9323 ⁱⁱ	— 23	+3.6	+5.8	40 23 52.16	+ 7 27.58	+1.21	+1.36	+13	22.44	+ 8	32.5
			33.8863 ^{iv}	10.0347 ⁱⁱ	+ 45	— .2	— .6	40 26 19.64	+10 2.59	+1.18	— 11	+17	23.47	+ 9	51.2
			28.4560	16.4230	+172	+ .7	— .2	40 31 18.90	+ 5 4.87	— 1	+ 9	+ 8	23.43	+ 9	
			18.7070	24.8777	— 47	+ .9	+ .3	40 41 4.61	— 4 42.04	+ 19	+ 19	—12	22.83	+ 7	50.2
	II		21.6350	20.7890	+ 7	+1.0	+1.1	40 36 43.66	— 21.89	+ 13	+ 31	— 1	22.70	+ 7	
			19.7827	20.0520	0	+ .3	— .5	40 36 29.78	— 6.80	+ 10	— 1	0	23.07	+ 7	
			12.2793	29.5590	+ 93	+ .9	— .4	40 29 6.31	+ 7 16.70	— 2	+ 10	+14	23.23	+ 8	48.5
			23.2843	18.9977	+ 30	—1.2	—1.5	40 38 10.68	— 1 48.35	+ 12	— 40	— 4	22.01	+ 8	48.4
			12.6310	30.4600	+163	— .5	— .8	40 28 52.49	+ 7 30.76	— 4	— 19	+13	23.15	+ 8	
Nov. 11	I	R	31.8583 ^{iv}	11.6110 ⁱⁱ	+ 3	— .2	— .4	40 27 50.43	+ 8 31.44	+1.19	— 8	+14	23.12	+ 8	
			14.4280 ⁱⁱ	30.2787 ^{iv}	— 56	+1.4	+1.9	40 29 40.65	+ 6 40.23	+1.21	+ 48	+12	22.69	+ 8	
			28.8917	13.8383	+122	—1.6	—1.8	40 42 44.74	— 6 20.54	+ 15	— 50	—11	23.74	+ 8	
			19.8270	22.1523	+ 14	+ .1	— .1	40 37 21.88	— 58.77	+ 13	0	— 2	23.22	+ 7	47.3
			23.7383	22.8550	+ 17	—2.6	—3.2	40 36 2.23	+ 22.35	+ 9	— 86	+ 1	23.82	+ 7	38.7
	II		12.9193 ⁱⁱ	31.8147 ^{iv}	— 15	—1.2	— .9	40 28 24.71	+ 7 57.28	+1.22	— 32	+15	23.04	+ 8	
			16.4783	28.5327	+177	—1.5	—2.7	40 31 18.78	+ 5 4.96	— 1	— 60	+ 8	23.21	+ 9	
			28.9697	17.9233	+223	—1.2	—2.4	40 41 4.59	— 4 39.61	+ 19	— 52	—12	24.53	+ 7	37.2
			22.7827	23.6053	+ 15	+ .5	— .1	40 36 43.69	— 20.82	+ 13	+ 7	— 1	23.06	+ 7	36.8
			23.2407	23.0043	+ 5	—2.0	—3.2	40 36 29.84	— 5.98	— 10	— 75	0	23.21	+ 7	

1892	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections.				Latitude	Δ	Ther.	
						A	B		Micrometer	δ	l	r				
Nov. 11	II	3	30.9540	13.6847	+236	— .7	—2.3	$\begin{smallmatrix} \circ & / & // \\ 40 & 29 & 6.42 \end{smallmatrix}$	+ 7 16.84	— 2	— 41	+14	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.97 \end{smallmatrix}$	+8	35.6	
		4	21.0013	25.2693	+ 79	— .2	— .9	$\begin{smallmatrix} \circ & / & // \\ 40 & 38 & 10.82 \end{smallmatrix}$	— 1 48.02	+ 12	— 15	— 4	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.73 \end{smallmatrix}$	+8	35.6	
		6	11.1087 ^{II}	31.3877 ^{IV}	0	—2.3	—4.2	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 50.67 \end{smallmatrix}$	+ 8 32.27	+1.19	— 93	+14	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.34 \end{smallmatrix}$	+8		
		7	31.1637 ^{IV}	15.2303 ^{II}	— 76	—4.8	—4.6	$\begin{smallmatrix} \circ & / & // \\ 40 & 29 & 40.91 \end{smallmatrix}$	+ 6 42.30	+1.21	—1.41	+12	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.13 \end{smallmatrix}$	+8		
		8	14.8967	29.9960	+218	+1.3	+1.6	$\begin{smallmatrix} \circ & / & // \\ 40 & 42 & 45.03 \end{smallmatrix}$	— 6 21.97	+ 15	+ 42	—11	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.52 \end{smallmatrix}$	+8		
Nov. 13	I	9	25.2543	22.9807	+ 53	—2.9	—3.5	$\begin{smallmatrix} \circ & / & // \\ 40 & 37 & 22.20 \end{smallmatrix}$	— 57.56	+ 13	— 95	— 2	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.80 \end{smallmatrix}$	+7	34.7	
		5	19.0670	24.0293	+ 44	— .8	—1.7	$\begin{smallmatrix} \circ & / & // \\ 40 & 34 & 18.57 \end{smallmatrix}$	+ 2 5.47	+ 3	— 36	+ 3	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.74 \end{smallmatrix}$	+8	39.7	
		6	19.9013	20.7400	+ 2	— .1	—1.3	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 1.99 \end{smallmatrix}$	+ 21.19	+ 9	— 18	+ 1	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.10 \end{smallmatrix}$	+7	37.9	
		7	30.3000 ^{IV}	11.4207 ^{II}	— 5	+ .3	—1.6	$\begin{smallmatrix} \circ & / & // \\ 40 & 28 & 24.51 \end{smallmatrix}$	+ 7 56.89	+1.22	— 15	+15	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 25.62 \end{smallmatrix}$	+8		
		8	32.6750 ^{IV}	8.8127 ^{II}	+ 18	— .8	—1.6	$\begin{smallmatrix} \circ & / & // \\ 40 & 26 & 19.28 \end{smallmatrix}$	+10 2.83	+1.18	— 34	+17	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.12 \end{smallmatrix}$	+8		
	II	9	27.2670	15.2107	+ 88	— .6	— .8	$\begin{smallmatrix} \circ & / & // \\ 40 & 31 & 18.61 \end{smallmatrix}$	+ 5 4.78	— 1	— 20	+ 8	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.26 \end{smallmatrix}$	+8	37.7	
		10	14.9373	26.0713	+ 33	— .8	+ .3	$\begin{smallmatrix} \circ & / & // \\ 40 & 41 & 4.50 \end{smallmatrix}$	— 4 41.34	+ 19	— 9	—12	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.14 \end{smallmatrix}$	+7		
		1	20.8150	19.9937	+ 3	+1.3	+2.3	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 43.62 \end{smallmatrix}$	— 20.75	+ 13	+ 51	— 1	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.50 \end{smallmatrix}$	+7		
		2	20.7363	20.9990	+ 0	— .4	—1.6	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 29.78 \end{smallmatrix}$	— 6.64	+ 10	— 27	0	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.97 \end{smallmatrix}$	+7	37.8	
		3	12.5447	29.8130	+119	+ .6	+ .4	$\begin{smallmatrix} \circ & / & // \\ 40 & 29 & 6.39 \end{smallmatrix}$	+ 7 16.51	— 2	+ 15	+14	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.17 \end{smallmatrix}$	+8	37.4	
		4	23.2783	19.0013	+ 30	+ .6	—1.6	$\begin{smallmatrix} \circ & / & // \\ 40 & 38 & 10.84 \end{smallmatrix}$	— 1 48.12	+ 12	— 10	— 4	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.70 \end{smallmatrix}$	+7		
		5	13.7820	31.5917	+282	+ .9	—1.2	$\begin{smallmatrix} \circ & / & // \\ 40 & 28 & 52.69 \end{smallmatrix}$	+ 7 30.60	— 4	0	+13	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.38 \end{smallmatrix}$	+8		
		6	31.8453 ^{IV}	11.5957 ^{II}	0	—1.6	—2.4	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 50.71 \end{smallmatrix}$	+ 8 31.53	+1.19	— 58	+14	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.99 \end{smallmatrix}$	+8		
		7	13.9580 ^{II}	29.8283 ^{IV}	— 44	— .8	— .4	$\begin{smallmatrix} \circ & / & // \\ 40 & 29 & 40.98 \end{smallmatrix}$	+ 6 40.79	+1.21	— 18	+12	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.92 \end{smallmatrix}$	+8		
		8	28.9703	13.8690	+127	— .1	— .2	$\begin{smallmatrix} \circ & / & // \\ 40 & 42 & 45.13 \end{smallmatrix}$	— 6 21.80	+ 16	— 4	—11	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.34 \end{smallmatrix}$	+8	37.0	
	VI	9	19.0237	21.3750	+ 5	— .9	—2.0	$\begin{smallmatrix} \circ & / & // \\ 40 & 37 & 22.32 \end{smallmatrix}$	— 59.41	+ 13	— 41	— 2	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.61 \end{smallmatrix}$	+7	37.0	
		3	12.6310	28.6740	+ 61	+ .3	+ .2	$\begin{smallmatrix} \circ & / & // \\ 40 & 43 & 8.36 \end{smallmatrix}$	— 6 45.43	+ 16	+ 7	—13	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.03 \end{smallmatrix}$	—3	37.0	
		4	18.5797	24.9590	+ 67	— .1	—1.4	$\begin{smallmatrix} \circ & / & // \\ 40 & 33 & 41.74 \end{smallmatrix}$	+ 2 41.32	+ 2	— 19	+ 5	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.94 \end{smallmatrix}$	—3	37.1	
		5	20.4083	25.7700	+ 97	—2.0	— .5	$\begin{smallmatrix} \circ & / & // \\ 40 & 38 & 38.96 \end{smallmatrix}$	— 2 15.69	+ 10	— 42	— 4	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.91 \end{smallmatrix}$	—3		
		6	33.8000 ^{IV}	12.4667 ^{II}	+ 26	— .9	— .2	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 22.79 \end{smallmatrix}$	+ 8 58.98	+1.22	— 18	+19	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.00 \end{smallmatrix}$	—3		
	Nov. 16		8	28.8277	12.6300	+ 68	+1.6	+ .2	$\begin{smallmatrix} \circ & / & // \\ 40 & 43 & 12.98 \end{smallmatrix}$	— 6 49.35	+ 16	+ 30	—12	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.97 \end{smallmatrix}$	—4	37.0
			9	12.5543 ^{II}	32.4947 ^{IV}	+ 0	+ .1	—1.1	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 58.53 \end{smallmatrix}$	+ 8 23.72	+1.21	— 12	+16	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.50 \end{smallmatrix}$	—4	
			10	19.6527	25.6473	+ 93	+ .4	— .6	$\begin{smallmatrix} \circ & / & // \\ 40 & 33 & 51.72 \end{smallmatrix}$	+ 2 31.67	+ 3	0	+ 4	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.46 \end{smallmatrix}$	—4	
			11	29.4350	16.7103	+230	—1.1	—1.1	$\begin{smallmatrix} \circ & / & // \\ 40 & 31 & 1.80 \end{smallmatrix}$	+ 5 22.02	— 0	— 33	+10	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.59 \end{smallmatrix}$	—4	
			12	12.0283	33.5973	+359	—1.4	—1.9	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 18.95 \end{smallmatrix}$	+ 9 5.77	— 5	— 48	+17	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 24.36 \end{smallmatrix}$	—4	35.4
VII		1	31.3967	16.6520	+350	—1.1	—1.6	$\begin{smallmatrix} \circ & / & // \\ 40 & 30 & 10.54 \end{smallmatrix}$	+ 6 13.36	— 0	— 39	+13	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.64 \end{smallmatrix}$	—4		
		2	18.6667	27.3207	+153	— .3	+ .4	$\begin{smallmatrix} \circ & / & // \\ 40 & 40 & 2.41 \end{smallmatrix}$	— 3 38.99	+ 11	0	— 7	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.46 \end{smallmatrix}$	—4		
		3	22.8863	19.5637	+ 23	—3.2	—2.7	$\begin{smallmatrix} \circ & / & // \\ 40 & 35 & 0.02 \end{smallmatrix}$	+ 1 24.00	+ 4	— 89	+ 3	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.20 \end{smallmatrix}$	—5	35.3	
		4	23.4243	17.0313	+ 8	—1.5	—2.3	$\begin{smallmatrix} \circ & / & // \\ 40 & 33 & 41.76 \end{smallmatrix}$	+ 2 41.51	+ 2	— 54	+ 5	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.80 \end{smallmatrix}$	—3	45.3	
		5	23.0957	17.7473	+ 13	—3.0	—3.2	$\begin{smallmatrix} \circ & / & // \\ 40 & 38 & 38.96 \end{smallmatrix}$	— 2 15.13	+ 10	— 92	— 4	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.97 \end{smallmatrix}$	—3		
		7	21.3693	18.9850	+ 00	+ .6	— .0	$\begin{smallmatrix} \circ & / & // \\ 40 & 37 & 23.04 \end{smallmatrix}$	— 1 0.23	+ 7	+ 10	— 2	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.96 \end{smallmatrix}$	—4	44.4	
		8	12.3710	28.5993	+ 47	+ .6	— .3	$\begin{smallmatrix} \circ & / & // \\ 40 & 43 & 12.89 \end{smallmatrix}$	— 6 50.05	+ 16	+ 6	—12	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.94 \end{smallmatrix}$	—4		
	9	29.6537 ^{IV}	9.7233 ^{II}	+ 0	— .7	— .6	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 58.39 \end{smallmatrix}$	+ 8 23.45	+1.21	— 19	+16	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.02 \end{smallmatrix}$	—4			
	10	23.0177	16.9767	0	—1.3	—3.2	$\begin{smallmatrix} \circ & / & // \\ 40 & 33 & 51.54 \end{smallmatrix}$	+ 2 32.59	+ 3	— 63	+ 4	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.57 \end{smallmatrix}$	—4	41.9		
	11	15.2477	27.9583	+120	— .5	— .9	$\begin{smallmatrix} \circ & / & // \\ 40 & 31 & 1.60 \end{smallmatrix}$	+ 5 21.38	— 0	— 20	+10	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.88 \end{smallmatrix}$	—4	42.1		
VII	12	30.2563	8.6877	— 67	—1.3	— .7	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 18.70 \end{smallmatrix}$	+ 9 4.66	— 5	— 31	+17	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.17 \end{smallmatrix}$	—4	42.1		
	1	11.7043	26.4950	— 79	—1.2	—1.8	$\begin{smallmatrix} \circ & / & // \\ 40 & 30 & 10.28 \end{smallmatrix}$	+ 6 13.42	— 0	— 43	+13	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.40 \end{smallmatrix}$	—4			
	2	24.5320	15.8497	+ 10	+ 3	0	$\begin{smallmatrix} \circ & / & // \\ 40 & 40 & 2.11 \end{smallmatrix}$	— 3 39.35	+ 11	+ 5	— 7	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.85 \end{smallmatrix}$	—5			
	3	17.0093	20.3380	— 26	— .7	—1.4	$\begin{smallmatrix} \circ & / & // \\ 40 & 34 & 59.69 \end{smallmatrix}$	+ 1 24.02	+ 4	— 30	+ 3	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.48 \end{smallmatrix}$	—5	41.0		
	5	11.9537	29.6147	+ 82	—1.2	—3.1	$\begin{smallmatrix} \circ & / & // \\ 40 & 28 & 57.93 \end{smallmatrix}$	+ 7 26.33	— 5	— 60	+13	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.74 \end{smallmatrix}$	—5	41.1		
Nov. 17	I	7	15.0390	26.7403	+ 61	— .2	—1.3	$\begin{smallmatrix} \circ & / & // \\ 40 & 41 & 19.24 \end{smallmatrix}$	— 4 55.74	+ 12	— 20	— 8	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.34 \end{smallmatrix}$	—5	40.4	
		8	8.8637 ^{II}	32.7473 ^{IV}	+ 19	+ .9	— .4	$\begin{smallmatrix} \circ & / & // \\ 40 & 26 & 18.95 \end{smallmatrix}$	+10 3.30	+1.18	+ 10	+17	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.70 \end{smallmatrix}$	+8	55.3	
		9	11.8830	23.9633	—148	+ .1	— .8	$\begin{smallmatrix} \circ & / & // \\ 40 & 31 & 18.32 \end{smallmatrix}$	+ 5 4.75	— 1	— 9	+ 8	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.05 \end{smallmatrix}$	+8		
		10	25.4193	14.2980	— 11	+ .1	—1.6	$\begin{smallmatrix} \circ & / & // \\ 40 & 41 & 4.35 \end{smallmatrix}$	— 4 40.87	+ 19	— 20	—12	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.35 \end{smallmatrix}$	+7	55.3	
		1	21.5277	22.3657	+ 12	+ .2	+1.2	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 43.51 \end{smallmatrix}$	— 21.20	+ 13	+ 19	— 1	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.62 \end{smallmatrix}$	+7	55.3	
		2	21.5427	21.2890	0	—1.5	—1.4	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 29.70 \end{smallmatrix}$	— 6.41	+ 10	— 43	0	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.96 \end{smallmatrix}$	+7		
		3	23.0480	10.7507	— 63	— .7	—2.9	$\begin{smallmatrix} \circ & / & // \\ 40 & 29 & 6.34 \end{smallmatrix}$	+ 7 16.74	— 2	— 49	+14	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.71 \end{smallmatrix}$	+8	53.5	
		4	19.5963	23.8617	+ 42	—1.8	— .2	$\begin{smallmatrix} \circ & / & // \\ 40 & 38 & 10.83 \end{smallmatrix}$	— 1 47.84	+ 12	— 33	— 4	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.74 \end{smallmatrix}$	+7		
		5	29.1567	11.3393	+ 26	—2.1	— .8	$\begin{smallmatrix} \circ & / & // \\ 40 & 28 & 52.71 \end{smallmatrix}$	+ 7 30.10	— 4	— 46	+13				

1892	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections.				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Nov. 20	II	7	28.9503 ^v	13.0967 ⁱⁱ	- 35	- .9	-1.5	40 29 41.09	+ 6 40.36	+1.21	- 35	+12	40 36 22.43	+8	
		8	12.4353	27.5600	- 1	-2.9	-1.5	40 42 45.28	- 6 22.01	+ 15	- 69	-11	22.62	+8	
	VI	7 R	23.2027	20.8307	+ 28	+ .8	0	40 37 22.51	- 59.99	+ 13	+ 13	- 2	22.76	+7	54.4
		8	18.9610	21.2617	+ 4	-2.2	-4.9	40 37 22.87	- 58.14	+ 7	-1.00	- 2	23.78	-4	32.0
		8	28.9653	12.8040	+ 84	-1.4	- .4	40 43 12.66	- 6 48.48	+ 16	- 29	-12	23.93	-4	
Nov. 22	VI	9	10.6513 ⁱⁱ	30.6013 ^{iv}	- 0	-1.3	-1.2	40 27 58.09	+ 8 23.98	+1.16	- 37	+16	23.02	-4	
		10	16.8540	22.8770	- 5	+1.7	+1.8	40 33 51.18	+ 2 32.14	+ 3	+ 52	+ 4	23.91	-4	32.5
		9 R	10.0157 ⁱⁱ	29.9720 ^{iv}	0	- .3	- .5	40 27 58.01	+ 8 24.16	+1.12	- 11	+16	23.34	-4	
	VI	10	16.7713	22.7907	- 8	+ .9	+ .4	40 33 50.96	+ 2 32.05	+ 3	+ 20	+ 4	23.28	-4	28.2
		11	26.1470	13.3913	-17	- .8	- .9	40 31 1.06	+ 5 22.20	- 0	- 25	+10	23.11	-4	27.7
	VII	2	10.9727	32.5430	+225	+1.0	- .3	40 27 18.05	+ 9 5.50	- 5	+ 13	+17	23.80	-4	
		2	15.2960	23.9317	- 21	-2.9	-1.5	40 40 1.33	- 3 38.11	+ 11	- 69	- 7	22.57	-5	
		3	21.8243	18.4680	+ 3	-1.7	- .9	40 34 58.84	+ 1 24.80	+ 4	- 40	+ 3	23.31	-5	
		5	29.3600	11.7087	+ 54	- .9	- .4	40 28 56.92	+ 7 26.04	- 5	- 20	+13	22.84	-5	
		6	27.7630	13.6850	+ 61	+ .7	+ .3	40 42 19.22	- 5 55.81	+ 14	+ 16	-10	23.61	-5	26.8
	Nov. 26	VI	7	25.9657	14.2837	+ 9	+ .8	0	40 41 17.99	- 4 55.15	+ 12	+ 13	- 8	23.01	-5
8			19.3770	21.6607	+ 9	- .2	+ .7	40 37 19.76	- 57.72	+ 6	+ 5	- 2	22.13	-5	
10			20.7647	21.6373	+ 8	+1.8	+1.9	40 36 43.95	- 22.06	+ 6	+ 55	- 1	22.49	-5	27.2
VI		10 D	22.5507	16.5010	-17	-1.3	-2.4	40 33 51.00	+ 2 32.79	+ 3	- 53	+ 4	23.33	-4	24.6
		11	13.6047	26.3847	0	-1.6	-1.0	40 31 0.96	+ 5 22.87	- 0	- 40	+10	23.53	-4	
VII		1	11.1823	25.9957	-124	+ .3	- .8	40 30 9.38	+ 6 13.93	- 0	- 5	+13	23.39	-4	24.5
		2	25.4947	16.8967	+ 61	-1.5	-1.8	40 40 1.07	- 3 37.38	+ 11	- 48	- 7	23.25	-5	
		3	17.5880	20.9727	-15	- .8	-1.4	40 34 58.53	+ 1 25.47	+ 4	- 31	+ 3	23.76	-5	
		5	12.5347	30.2310	+142	- .8	-2.2	40 28 56.50	+ 7 27.43	- 5	- 42	+13	23.59	-5	
		6	13.1140	27.1880	+ 13	+ .1	-1.2	40 42 18.72	- 5 55.60	+ 12	- 14	-10	23.00	-5	22.3
Dec. 1	II	2	13.8847	25.5340	-19	- .5	-1.7	40 41 17.40	- 4 54.26	+ 12	- 30	- 8	22.88	-5	
		8	20.8523	18.6750	- 2	-1.6	-2.9	40 37 19.10	- 55.00	+ 6	- 65	- 2	23.49	-5	22.3
		9	12.4800	25.1400	-90	-1.4	-1.5	40 31 4.17	+ 5 19.61	+ 2	- 43	+11	23.48	-5	
	VIII	10	20.1767	19.3977	0	- .6	-1.2	40 36 43.18	- 19.68	+ 6	- 25	- 1	23.30	-5	22.3
		1	18.2933	21.3187	- 4	- .2	- .7	40 37 39.20	- 1 16.42	+ 7	- 12	- 2	22.71	-5	22.3
	II	2 D	25.8810	13.5353	- 21	-1.2	-1.3	40 31 10.68	+ 5 11.85	+ 3	- 37	+12	22.31	-5	22.2
		3	11.7883	29.1067	+ 45	-1.7	-3.4	40 29 5.90	+ 7 17.62	+ 3	- 73	+14	22.96	+7	30.5
		4	22.0540	17.7850	- 2	-1.0	-1.5	40 38 10.67	- 1 47.84	+ 11	- 36	- 4	22.54	+7	
		5	12.1303	29.9367	+107	- .5	-1.1	40 28 52.56	+ 7 30.10	+ 2	- 22	+13	22.59	+8	30.4
		6	31.0253 ^{iv}	10.8203 ⁱⁱ	0	- .7	+ .1	40 27 50.86	+ 8 30.43	+1.05	- 10	+14	22.38	+8	
Dec. 2	III	7	12.1153 ⁱⁱ	27.9560 ^{iv}	- 1	+ .5	+ .7	40 29 41.28	+ 6 40.17	+1.06	+ 17	+12	22.80	+8	
		8	28.2353	13.0833	+ 59	+1.7	+ .9	40 42 45.66	- 6 22.92	+ 11	+ 40	-11	23.14	+8	
		9	20.4403	22.8487	+ 23	+ .8	+ .7	40 37 23.12	- 1 0.90	+ 13	+ 22	- 2	22.55	+7	30.1
	III	1	16.7253	24.9920	+ 42	- .2	- .2	40 39 51.68	- 3 28.94	+ 8	- 6	- 6	22.70	+8	29.9
		2	5.8713 ⁱⁱ	34.5057 ^{iv}	+ 10	+ .3	+ .4	40 24 18.18	+12 3.40	+1.05	+ 10	+21	22.94	+7	
	II	3	25.0677	14.0140	- 30	+ .8	+ .1	40 41 1.72	- 4 39.17	+ 10	+ 15	- 8	22.72	+7	29.9
		5	17.5073	21.4103	-14	-2.9	-2.2	40 38 2.23	- 1 38.56	+ 8	- 78	- 3	22.94	+7	
		6	26.1617	12.1393	- 71	+2.0	+2.1	40 42 17.18	- 5 54.06	+ 17	+ 61	-14	23.76	+6	
		7	17.6567	23.5633	+ 21	- .4	+1.8	40 38 52.45	- 2 29.27	+ 7	+ 16	- 4	23.37	+7	30.1
		8 R	30.5257	13.2403	+193	+1.1	- .5	40 29 5.87	+ 7 17.14	+ 3	+ 12	+14	23.30	+7	35.4
Dec. 2	III	4	18.2100	22.4733	+ 9	-2.1	-2.0	40 38 10.64	- 1 47.72	+ 11	- 62	- 4	22.37	+7	35.0
		5	29.3710	11.5490	+ 47	- .8	-1.2	40 28 52.54	+ 7 30.34	+ 2	- 29	+13	22.74	+8	
		6	10.2647 ⁱⁱ	30.5017 ^{iv}	0	+ .6	- .2	40 27 50.86	+ 8 31.22	+1.01	+ 7	+14	23.30	+8	
		7	27.8563 ^{iv}	11.9827 ⁱⁱ	+ 2	-2.2	-2.5	40 29 41.28	+ 6 41.00	+1.02	- 70	+12	22.72	+8	
		8	12.5187	27.6343	+ 5	-2.0	-1.7	40 42 45.67	- 6 21.86	+ 11	- 56	-11	23.25	+8	
	III	9	22.3557	20.0000	+ 18	-1.6	-1.8	40 37 23.16	- 59.55	+ 13	- 50	- 2	23.22	+7	33.7
		1	24.4273	16.1870	+ 15	- .1	- .2	40 39 51.72	- 3 28.21	+ 8	- 4	- 6	23.49	+8	33.4
		2	34.6310 ^{iv}	5.9597 ⁱⁱ	+ 16	- .9	-2.1	40 24 18.23	+12 4.33	+1.01	- 42	+21	23.36	+7	
		4	15.7830	27.4483	+113	-1.4	- .3	40 41 18.42	- 4 54.97	+ 9	- 28	- 8	23.18	+7	33.5
		5	22.7487	18.8283	+ 19	- .8	- .2	40 38 2.32	- 1 39.09	+ 8	- 16	- 3	23.12	+7	33.3

1892	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections.				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Dec. 2	III 6		13.9450	27.9417	+ 79	0	-1.0	40 42 17.26	- 5 53.78	+ 16	- 13	-14	40 36 23.37	+6	33.5
	7		21.7507	15.8313	- 41	- .3	-1.5	40 38 52.55	- 2 29.43	+ 7	- 24	- 4	22.91	+7	33.5
Dec. 3	8		15.1960	25.7843	+ 31	-2.6	-2.9	40 40 51.67	- 4 27.56	+ 11	- 82	- 9	23.31	+6	33.8
	II 3	D	11.4737	28.7547	+ 12	+2.3	+ .2	40 29 5.84	+ 7 16.56	+ 3	+ 41	+14	22.98	+7	41.5
	6		29.3603 ^{iv}	9.1443 ⁱⁱ	0	- .6	- .9	40 27 50.86	+ 8 30.67	-1.01	- 21	+14	22.47	+8	
	7		12.0283 ⁱⁱ	27.8530 ^{iv}	+ 2	+2.4	+1.6	40 29 41.29	+ 6 39.74	+1.02	+ 61	+12	22.78	+8	
	8		27.4493	12.2940	- 12	+1.7	+ .6	40 42 45.70	- 6 22.80	+ 11	+ 36	-11	23.26	+8	41.1
	9		18.8677	21.2647	+ 1	- .7	-1.2	40 37 23.20	- 1 0.55	+ 13	- 27	- 2	22.49	+7	41.1
	III 1		17.2477	25.5123	+ 66	-1.0	-2.3	40 39 51.77	- 3 28.94	+ 8	- 46	- 6	22.39	+8	
	2		6.0847 ⁱⁱ	34.7057 ^{iv}	+ 21	+ .6	+ .8	40 24 18.28	+12 3.04	+1.01	+ 20	+21	22.74	+7	40.0
	3		24.5407	13.4890	- 63	- .4	- .4	40 41 1.85	- 4 39.01	+ 10	- 12	- 8	22.74	-7	
	4		26.7793	15.1037	+ 68	-1.4	-2.0	40 41 18.50	- 4 55.10	+ 9	- 50	- 8	22.91	+7	39.4
	5		17.7960	21.7303	- 8	- .4	- .7	40 38 2.40	- 1 39.36	+ 8	- 16	- 3	22.93	+7	
	6		25.9750	11.9223	- 88	+2.5	+3.1	40 42 17.36	- 5 54.75	+ 17	+ 82	-14	23.46	+6	38.8
	7		17.7643	23.6893	+ 25	- .8	- .3	40 38 52.66	- 2 29.74	+ 7	- 17	- 4	22.78	+7	38.3
Dec. 5	8		24.9413	14.2900	- 25	+2.1	+1.6	40 40 51.79	- 4 29.00	+ 11	+ 56	- 9	23.37	+6	
	9		13.9437	25.5230	- 17	+1.1	+1.3	40 31 30.45	+ 4 52.46	+ 7	+ 36	+11	23.45	+6	
	II 10		8.6423 ⁱⁱ	30.1400 ^{iv}	- 6	0	0	40 27 18.53	+ 9 3.03	+1.01	0	+15	22.72	+6	37.8
	3	R	28.8523	11.6080	+ 23	+1.2	+ .3	40 29 5.77	+ 7 15.69	+ 3	+ 24	+14	21.87	+7	31.5
	5		29.5650	11.7630	+ 69	-1.0	- .9	40 28 52.50	+ 7 29.90	+ 2	- 28	+13	22.27	+7	31.2
	6		9.5543 ⁱⁱ	29.7740 ^{iv}	0	+ .3	0	40 27 50.85	+ 8 30.80	+1.01	+ 5	+14	22.85	+8	
	7		27.8103 ^{iv}	11.9513 ⁱⁱ	+ 3	-1.3	-1.8	40 29 41.30	+ 6 40.64	+1.02	- 45	+12	22.63	+8	
	8		12.8107	27.9417	+ 34	- .8	0	40 42 45.75	- 6 22.33	+ 11	- 13	-11	23.29	+8	
	9		21.7767	19.4033	+ 10	- .5	-1.6	40 37 23.30	- 59.99	+ 13	- 29	- 2	23.13	+6	30.6
	III 1		24.6607	16.3993	+ 26	- .3	-1.5	40 39 51.87	- 3 28.77	+ 8	- 24	- 6	22.88	+8	
	2		32.4173 ^{iv}	3.7707 ⁱⁱ	- 96	-2.9	-1.6	40 24 18.40	+12 3.45	+1.01	- 70	+21	22.37	+7	
	3		15.5893	26.5980	+ 71	-3.4	-2.8	40 41 1.99	- 4 33.29	+ 10	- 94	- 8	22.78	+7	29.9
	4		14.2750	25.9713	+ 9	- .8	- .4	40 41 18.67	- 4 55.50	+ 9	- 18	- 8	23.00	+7	
	5		22.6020	18.6673	+ 16	+ .2	- .6	40 38 2.60	- 1 39.44	+ 8	- 4	- 3	23.17	+7	
	6		18.7920	27.7703	+ 67	-4.1	-3.9	40 42 17.57	- 5 53.30	+ 16	-1.20	-14	23.09	+6	
	7		22.5347	16.6580	- 15	-1.6	-4.0	40 38 52.89	- 2 28.43	+ 7	- 79	- 4	23.70	+7	23.96
	8		15.9253	26.5363	+ 75	-2.8	-3.8	40 40 52.04	- 4 23.25	+ 11	- 96	- 9	22.85	+6	
	9		27.2727	15.6840	+103	-3.8	-4.0	40 31 30.71	+ 4 53.02	+ 7	-1.16	+11	22.75	+6	
	10		31.3463 ^{iv}	9.8207 ⁱⁱ	+ 5	+ .1	- .7	40 27 18.80	+ 9 3.80	+1.01	- 7	+15	23.69	+6	29.4
	VI 12	R	10.0173	31.6677	+108	-3.2	-2.4	40 27 17.22	+ 9 7.22	+ 2	- 85	+17	23.78	-4	
	VII 1		27.8333	13.0030	+ 36	+1.3	-1.3	40 30 8.70	+ 6 14.75	+ 4	+ 5	+13	23.67	-4	
	2		15.7893	24.3733	+ 6	-2.3	-1.2	40 40 0.29	- 3 36.87	+ 8	- 54	- 7	22.89	-5	
	3		21.5310	18.1180	- 4	-1.6	-2.0	40 34 57.65	+ 1 26.21	+ 5	- 53	+ 3	23.41	-5	25.9
	4		24.8580	16.1477	+ 26	+ .3	+ .6	40 40 3.12	- 3 40.12	+ 13	+ 12	- 9	23.16	-5	
	5		28.6377	10.9187	- 25	-1.5	+ .4	40 28 55.39	+ 7 27.58	+ 1	- 20	+13	22.91	-5	
	6		28.0653	14.0530	+ 88	- .6	- .9	40 42 17.47	- 5 54.22	+ 10	- 21	-10	23.04	-6	25.8
	7		25.9453	14.3863	+ 11	-2.4	-2.5	40 41 15.98	- 4 52.04	+ 9	- 73	- 8	23.22	-6	
	8		19.2800	21.4083	+ 3	- .8	-1.6	40 37 17.57	- 53.78	+ 6	- 34	- 2	23.49	-6	25.4
	9		27.6157	14.9137	+ 95	+ .6	+1.4	40 31 2.59	+ 5 21.14	+ 6	+ 28	+11	24.18	-5	
	10		20.2823	20.9737	0	- .8	- .8	40 36 41.44	- 17.46	+ 6	- 24	- 1	23.79	-6	
Dec. 9	VIII 1		21.4160	18.5030	- 1	- .6	-1.3	40 37 37.32	- 1 13.59	+ 7	- 27	- 2	23.51	-6	24.7
	2		15.4433	27.8943	+123	- .1	- .8	40 31 8.78	+ 5 14.87	+ 7	- 12	+12	23.72	-5	
	VII 1	D	10.5773	25.4183	-176	+ .3	+ .4	40 30 8.60	+ 6 14.47	+ 4	+ 10	+13	23.34	-4	29.1
	2		23.2840	14.7170	- 50	- .1	- .2	40 40 0.15	- 3 36.30	+ 8	- 4	- 7	23.82	-5	
	3		16.0450	19.4757	- 44	- .3	- .8	40 34 57.46	+ 1 26.56	+ 5	- 15	+ 3	23.95	-5	29.3
	5		14.5120	32.2280	+352	- .3	- .8	40 28 55.09	+ 7 28.44	+ 1	- 15	+13	23.52	-5	
	6		14.1753	23.1557	+ 93	-1.0	-2.4	40 42 17.09	- 5 53.42	+ 9	- 48	-10	23.18	-6	
	7		13.6737	25.2077	- 39	-2.6	-3.0	40 41 15.52	- 4 51.28	+ 9	- 83	- 8	23.42	-6	28.6
	8		22.9347	20.8337	+ 22	-1.2	-1.7	40 37 17.05	- 53.14	+ 6	- 42	- 2	23.53	-6	27.8
	10		20.6143	19.9340	0	+ .4	+ .8	40 36 40.79	- 17.18	+ 6	+ 17	- 1	23.83	-6	28.2

1892	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections.				Latitude	Δ	Ther.
						A	B		Micrometer	δ	δ'	r			
Dec. 10	II	D	21.0663	16.7940	-27	+ .8	+ .5	40 38 10.24	-1 47.86	+ 11	+ 20	- 4	40 36 22.65	+6	
			11.8393	29.6693	+79	-.3	-.8	40 28 52.11	+7 30.63	+ 2	- 15	+13	22.74	+7	31.2
			29.8993 ^{iv}	9.6520 ⁱⁱ	0	-2.1	-1.6	40 27 50.55	+8 31.50	+1.01	- 56	+14	22.64	+7	
			12.2753 ⁱⁱ	28.0700 ^{iv}	-5	+4.6	+5.3	40 29 41.05	+6 39.00	+1.02	+1.47	+12	22.66	+7	30.4
			27.5123	12.3783	-4	-.1	-1.1	40 42 45.58	-6 22.31	+ 11	- 15	-11	23.12	+7	
	III	1	16.5427	24.7857	+30	-1.5	-1.2	40 39 51.86	-3 28.31	+ 8	- 41	- 6	23.16	+7	30.2
			8.4803 ⁱⁱ	37.0827 ^{iv}	+141	+1.6	+ .9	40 24 18.46	+12 2.92	+1.01	+ 39	+21	22.99	+7	
			25.6640	14.5843	+8	+2.0	+2.0	40 41 2.11	-4 39.92	+ 10	+ 60	- 8	22.81	+7	
			25.8787	14.1643	+2	-.1	-.6	40 41 18.86	-4 55.94	+ 9	- 9	- 8	22.84	+7	30.0
			17.0000	20.9463	-24	-1.4	-1.4	40 38 2.89	-1 39.63	+ 8	- 42	- 3	22.89	+7	
			26.5843	12.5360	-38	+ .6	+ .7	40 42 17.93	-5 54.80	+ 17	+ 19	-14	23.35	+6	29.7
			17.9987	23.9307	+33	-1.8	-1.2	40 38 53.30	-2 29.94	+ 7	- 46	- 4	22.93	+7	29.6
			24.1550	13.4850	-74	+ .8	+ .7	40 40 52.53	-4 29.36	+ 11	+ 22	- 9	23.41	+6	
			15.0920	26.6523	+59	0	-1.4	40 31 31.22	+4 52.19	+ 8	- 18	+11	23.42	+6	
			11.4597 ⁱⁱ	32.9440 ^{iv}	+18	+ .6	-.8	40 27 19.33	+9 2.79	+1.01	- 0	+15	23.28	+6	29.9
Dec. 11	VII	R	25.8620	17.2083	+77	-3.3	-3.0	40 40 2.81	-3 38.81	+ 13	- 95	- 9	23.09	-5	26.3
			29.1893	11.4367	+33	-1.7	-1.9	40 28 55.01	+7 28.57	+ 1	- 53	+13	23.19	-6	
			26.9850	12.9887	0	-.8	-.9	40 42 16.98	-5 53.59	+ 10	- 25	-10	23.14	-6	27.4
			26.4723	14.9190	+48	-.5	-1.8	40 41 15.36	-4 51.99	+ 9	- 31	- 8	23.07	-6	
			19.2790	21.4050	+6	-3.5	-2.0	40 37 16.87	-53.73	+ 6	- 85	- 2	22.33	-6	27.0
			27.8337	15.0980	+111	-1.0	-1.7	40 31 1.82	+5 22.02	+ 6	- 39	+11	23.62	-6	
			20.6600	21.3293	+3	-1.3	-1.1	40 36 40.55	-16.91	+ 6	- 36	- 1	23.33	-6	
			21.5297	18.6433	+1	-.5	-1.8	40 37 36.34	-1 12.92	+ 7	- 31	- 2	23.16	-6	
	VIII	2	15.3047	27.7870	+115	0	-.6	40 31 7.74	+5 15.63	+ 7	- 7	+12	23.49	-6	
			14.9387	26.9270	+65	-3.0	-2.0	40 41 26.87	-5 3.03	+ 9	- 77	- 9	23.07	-6	
Dec. 12	II	R	14.7850	23.4397	-44	-.5	-1.6	40 32 45.26	+3 38.53	+ 3	- 29	+ 6	23.59	-6	26.7
			30.9377 ^{iv}	10.9443 ⁱⁱ	0	-3.0	-1.9	40 27 57.94	+8 25.10	+1.04	- 75	+16	23.49	-6	
			20.4923	23.3117	+31	+ .4	+ .3	40 37 34.33	-1 11.31	+ 8	+ 12	- 2	23.20	-6	26.0
			28.9580	11.1233	-4	+ .5	-1.0	40 28 51.87	+7 30.55	+ 1	- 21	+13	22.35	+7	33.0
			9.1423 ⁱⁱ	29.3803 ^{iv}	0	+ .9	0	40 27 50.33	+8 31.26	+ 97	+ 15	+14	22.85	+7	
			28.2790 ^{iv}	12.4310 ⁱⁱ	-9	+1.0	0	40 29 40.85	+6 40.33	+ 98	+ 17	+12	22.45	+7	
			14.0407	29.1510	+142	-.7	+ .3	40 42 45.42	-6 22.08	+ 11	- 7	-11	23.27	+7	33.2
			21.5193	19.1470	+4	+ .1	-.9	40 37 23.16	-59.94	+ 13	- 10	- 2	23.23	+6	
	III	1	23.9220	15.6830	-10	0	-.2	40 39 51.75	-3 28.11	+ 8	- 2	- 6	23.64	+7	32.6
			32.0733 ^{iv}	3.4307 ⁱⁱ	-115	+ .3	-.4	40 24 18.37	+12 3.28	+ 97	0	+21	22.83	+7	
Dec. 15	VII	D	15.1537	26.1910	+45	+ .4	+ .2	40 41 2.04	-4 38.94	+ 10	+ 9	- 8	23.21	+7	
			14.1767	25.8763	+2	-.2	-.6	40 41 18.82	-4 55.56	+ 9	- 11	- 8	23.16	+7	32.6
			15.2990	29.2927	+189	-.6	-.3	40 42 17.96	-5 53.98	+ 16	- 14	-14	23.86	+6	32.5
			21.3000	15.3603	-58	+ .4	-.7	40 38 53.36	-2 29.90	+ 7	- 2	- 4	23.47	+7	
			15.4403	26.0660	+47	-2.9	-2.3	40 40 52.61	-4 28.55	+ 11	- 72	- 9	23.36	+6	
			27.6443	16.1210	+129	+ .2	+1.1	40 31 31.31	+4 51.43	+ 7	+ 17	+11	23.09	+6	
			31.5383 ^{iv}	10.0710 ⁱⁱ	+6	-.2	-.2	40 27 19.45	+9 2.32	+ 97	- 6	+15	22.83	+6	31.5
			15.4810	24.2010	-7	+1.7	+1.2	40 40 2.59	-3 40.27	+ 13	+ 44	- 9	22.80	-5	33.4
			12.5773	30.3193	+151	+ .6	-.1	40 28 54.75	+7 28.58	+ 1	+ 8	+13	23.55	-6	
			13.8523	25.4083	-26	+ .3	+ .5	40 41 14.96	-4 51.87	+ 9	+ 11	- 8	23.21	-6	
Dec. 17	VII	D	14.2723	22.9543	-71	-.4	-.8	40 40 2.44	-3 39.15	+ 13	- 17	- 9	23.16	-5	30.2
			11.6707	29.4313	+57	-1.2	-1.1	40 28 54.58	+7 28.83	+ 1	- 34	+13	23.20	-6	
			12.6280	26.6247	-32	-.1	-.2	40 42 16.48	-5 53.51	+ 10	- 4	-10	22.93	-6	29.5
			14.3947	25.9227	+10	-1.0	-.6	40 41 14.76	-4 51.25	+ 9	- 24	- 8	23.28	-6	
			19.1790	12.1790	+4	-1.5	-.7	40 37 16.20	-52.74	+ 6	- 34	- 2	23.16	-6	29.6
			14.2013	26.9537	+45	-.1	-.8	40 31 1.09	+5 22.28	+ 6	- 12	+11	23.42	-6	
			21.4510	20.7657	+3	-.2	+ .1	40 36 39.74	-17.32	+ 6	- 2	- 1	22.45	-6	29.0
			18.0190	20.8850	-9	-1.7	-1.9	40 37 35.45	-1 12.88	+ 7	- 53	- 2	22.59	-6	28.8
	VIII	2	27.1297	14.6197	+63	-1.1	0	40 31 6.80	+5 16.20	+ 7	- 19	+12	22.60	-6	29.4
			26.4030	14.3970	+28	+2.0	+ .8	40 41 25.80	-5 3.37	+ 9	+ 44	- 9	22.87	-7	

1892	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections.				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Dec. 17	VIII 4		24.9103	16.2577	+ 29	-1.1	-.6	40 32 44.06	+ 3 38.66	+ 3	- 26	+ 6	22.55	-7	
			9.1500 ^{II}	29.1537 ^{IV}	0	-.3	-1.1	40 27 56.80	+ 8 25.35	+ 93	- 19	+ 16	23.05	-6	29.3
			21.4763	18.6883	+ 2	+2.1	+1.0	40 37 33.11	- 1 10.44	+ 8	+ 49	- 2	23.22	-6	
			28.3923 ^{IV}	12.1887 ^{II}	- 7	-.8	-.4	40 29 32.21	+ 6 49.33	+ 92	- 18	+ 12	22.40	-6	30.0
			19.4690	20.4453	+ 1	-.1	.1	40 35 58.58	+ 24.66	+ 10	- 3	+ 1	23.32	-6	29.5
Dec. 19	VII 8 R		12.6523	26.6467	- 29	-.5	-.3	40 30 29.64	+ 5 53.46	+ 5	- 12	+ 11	23.14	-6	29.4
			19.2960	21.8933	+ 6	-1.1	-1.4	40 37 16.08	- 53.00	+ 6	- 37	- 2	22.75	-6	32.0
			27.3747	14.6163	+ 76	-1.6	-1.2	40 31 0.95	+ 5 22.50	+ 6	- 43	+ 11	23.19	-6	31.7
			21.4873	22.1270	+ 8	-1.8	-2.6	40 36 39.59	- 16.18	+ 6	- 64	- 1	22.82	-6	
	VIII 1		22.8010	19.9737	+ 26	+ .1	-.6	40 37 35.27	- 1 11.49	+ 7	- 6	- 2	23.77	-6	
			14.5030	27.0053	+ 55	+ .1	-.2	40 31 6.62	+ 5 15.97	+ 7	- 1	+ 12	22.77	-6	31.8a
			14.8567	26.8200	+ 60	-.2	+.6	40 41 25.60	- 5 2.37	+ 9	+ 4	- 9	23.27	-7	a
			16.1890	24.8667	+ 28	0	-.2	40 32 43.84	+ 3 39.29	+ 3	- 2	+ 6	23.20	-7	
			30.6300 ^{IV}	10.6303 ^{II}	0	-.8	+.1	40 27 56.58	+ 8 25.24	+ 89	- 12	+ 16	22.75	-6	32.4
			17.5950	20.3653	- 17	-.6	+.1	40 37 32.88	- 1 9.94	+ 8	- 8	- 2	22.92	-6	
Dec. 20	II 8 D		12.0950 ^{II}	23.3330 ^{IV}	- 4	-.3	-2.1	40 29 31.96	+ 6 50.20	+ 88	- 32	+ 12	22.84	-7	32.0
			22.5363	21.5700	+ 11	-1.5	-.1	40 35 58.39	- 24.44	+ 11	- 27	+ 1	22.68	-6	32.0
			28.0407	12.9657	+ 44	+ .4	-.4	40 42 44.94	- 6 20.96	+ 11	+ 2	- 11	24.00	+6	26.5
			21.4307	23.7820	+ 37	-1.2	-2.1	40 37 22.92	- 59.50	+ 13	- 47	- 2	23.06	+6	
	III 1		17.2663	25.5073	+ 67	-1.2	-1.9	40 39 51.46	- 3 28.36	+ 8	- 45	- 6	22.67	+7	
			8.5023 ^{II}	37.1207 ^{IV}	+142	-1.0	-1.8	40 24 18.17	+12 3.36	+ 86	- 40	+ 21	22.20	+7	25.9
			26.1667	15.1103	+ 42	+ .2	-.2	40 41 1.94	- 4 39.43	+ 10	+ 1	- 8	22.54	+7	
			26.6357	14.9420	+ 52	-.6	-1.0	40 41 18.81	- 4 55.55	+ 9	- 23	- 8	23.04	+7	25.6
			17.7520	21.7430	- 7	+ .7	+.1	40 38 3.03	- 1 40.80	+ 8	+ 13	- 3	22.41	+6	24.8
			26.9613	12.8680	- 7	-.4	-1.2	40 42 18.18	- 5 56.02	+ 17	- 22	- 14	21.97	+6	
Dec. 22	VII 9 D		17.6463	23.5840	+ 21	-2.7	-2.0	40 38 53.65	- 2 30.06	+ 8	- 72	- 4	22.90	+7	24.1
			25.1803	14.5153	- 11	-1.4	-2.5	40 40 53.02	- 4 29.41	+ 11	- 56	- 9	23.07	+6	
			14.7703	26.3080	+ 38	-.6	-1.3	40 31 31.77	+ 4 51.57	+ 7	- 27	+ 11	23.25	+6	
			8.3123 ^{II}	29.7987 ^{IV}	- 8	-2.2	-2.6	40 27 19.94	+ 9 2.80	+ 86	- 71	+ 15	23.04	+6	23.2
	VIII 1 D		12.6607	25.4550	- 72	-.8	-1.2	40 31 0.52	+ 5 23.06	+ 6	- 29	+ 11	23.46	-6	20.5b
			20.1823	19.5553	0	-1.2	-2.6	40 36 39.10	- 15.84	+ 6	- 54	- 1	22.77	-6	
			24.3543	16.1130	+ 12	+ .3	-.2	40 39 51.26	- 3 28.23	+ 8	+ 2	- 6	23.07	+7	24.0
			34.0690 ^{IV}	5.4463 ^{II}	- 12	+1.6	+1.4	40 24 18.02	+12 3.08	+ 86	+ 45	+ 21	22.62	+6	
			15.1277	26.1287	+ 40	-3.1	-2.0	40 41 1.83	- 4 38.02	+ 10	- 79	- 8	23.04	+6	
			14.3437	26.0487	+ 10	+ .5	+.2	40 41 18.75	- 4 55.74	+ 9	+ 11	- 8	23.13	+7	23.7
Dec. 25	VIII 1 D		23.3003	19.3613	+ 31	-2.0	-1.9	40 38 3.04	- 1 39.60	+ 8	- 58	- 3	22.91	+6	
			13.6520	27.6883	+ 56	-.1	-.6	40 42 18.30	- 5 54.74	+ 17	- 9	- 14	23.50	+6	
			22.8130	16.8650	- 6	-.9	-2.5	40 38 53.74	- 2 30.25	+ 7	- 48	- 4	23.04	+7	23.5
			15.2200	25.8947	+ 34	0	-.5	40 40 53.18	- 4 29.77	+ 11	- 6	- 9	23.37	+6	
	VIII 1 D		21.2620	24.0663	+ 42	-1.4	-1.5	40 37 34.47	- 1 10.96	+ 6	- 43	- 2	23.12	-7	14.8
			26.5417	13.9587	+ 19	-2.0	-1.9	40 31 5.69	+ 5 17.96	+ 11	- 58	+ 12	23.30	-6	b
			24.7530	15.9897	+ 21	-3.7	-2.4	40 32 42.61	+ 3 41.46	+ 6	- 94	+ 6	23.25	-7	14.8
			10.2310 ^{II}	30.2740 ^{IV}	0	-.1	-1.3	40 27 55.37	+ 8 26.39	+ 96	- 18	+ 16	22.70	-7	
			28.0273 ^{IV}	11.7537 ^{II}	+ 2	-.5	+2.1	40 29 30.55	+ 6 51.16	+ 93	+ 18	+ 12	22.94	-7	
			11.9110	25.9937	- 88	+ .6	+.1	40 30 27.89	+ 5 55.58	+ 9	+ 11	+ 11	23.78	-7	14.0
Dec. 26	III 2 D		37.6187 ^{IV}	10.2210 ^{II}	+171	-.5	-1.5	40 47 57.32	-11 32.64	- 80	- 28	- 23	23.37	-6	
			13.7323	28.8560	+115	+ .3	+1.7	40 42 45.12	- 6 22.39	+ 5	+ 27	- 12	22.92	-7	14.4
			2.9480 ^{II}	31.6717 ^{IV}	-138	-2.3	-1.8	40 24 17.74	+12 5.35	+ 95	- 62	+ 21	23.63	+6	17.3
			24.6590	13.5933	- 56	+2.3	+2.0	40 41 1.59	- 4 39.43	+ 6	+ 65	- 8	22.79	+6	
	VIII 1 D		25.0327	13.3457	- 57	-1.4	-.2	40 41 18.54	- 4 55.13	+ 5	- 26	- 8	23.12	+7	16.6
			18.6900	22.6447	+ 16	-1.1	-.8	40 38 2.91	- 1 39.95	+ 7	- 29	- 3	22.71	+6	16.5
			26.2063	12.1443	- 71	+1.1	+.2	40 42 18.23	- 5 55.09	+ 12	+ 21	- 14	23.33	+5	
			18.0340	24.0307	+ 35	+ .8	+2.4	40 38 53.68	- 2 31.59	+ 5	+ 44	- 4	22.54	+6	16.2
			25.2023	14.5423	- 9	-.4	-.6	40 40 53.18	- 4 29.31	+ 7	- 14	- 9	23.71	+6	16.0
			13.3763	24.8787	- 59	+1.4	+.9	40 31 31.97	+ 4 50.46	+ 11	+ 35	+ 11	23.00	+5	

1892	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Dec. 26	III 10	D	9.0527 ^u	30.5107 ^{iv}	+ 1	-1.2	-.2	40 27 20.15	+ 9 2.14	+ 93	- 23	+15	40 36 23.14	+6	16.2
	IV 1		20.8203	18.0490	- 9	+ .3	+ .2	40 35 12.74	+ 1 9.99	+ 8	+ 7	+ 2	22.90	+5	15.6
	2		15.8827	26.8157	+ 74	-.2	+ .8	40 41 11.91	- 4 49.04	+ 5	+ 7	- 8	22.91	+6	14.5
	3		28.8280	8.7093	-172	+1.0	+ .3	40 44 37.47	- 8 15.23	+ 7	+ 21	-17	22.35	+5	
	4		28.1710	9.5270	-127	+ .4	+ .2	40 44 14.11	- 7 50.90	+ 4	+ 9	-14	23.20	+5	
	5		16.9187	20.9623	- 26	+1.5	+ .9	40 34 40.38	+ 1 42.09	+ 5	+ 37	+ 3	22.92	+5	15.0
	8		14.0260	26.6030	+ 23	+ .7	+1.7	40 41 39.85	- 5 17.82	+ 7	+ 34	-11	22.33	+4	15.0
	9		25.4020	12.6153	- 77	+1.7	+1.5	40 30 59.46	+ 5 22.86	+ 8	+ 48	+10	22.98	+4	
	10		27.9003 ^{iv}	6.5590 ^u	- 21	-.8	+ .2	40 27 22.06	+ 8 59.13	+ 95	- 11	+17	22.20	+3	14.4
	III 1	R	23.1600	14.9160	- 47	+1.9	+1.7	40 39 50.83	- 3 28.17	+ 5	+ 54	- 6	23.19	+6	23.0
Dec. 27	2		34.1957 ^{iv}	5.5473 ^u	- 7	+1.8	+ .8	40 24 17.65	+12 3.76	+ 95	+ 41	+21	22.98	+6	22.5
	3		15.8637	26.4067	+ 58	+3.3	+2.7	40 41 1.51	- 4 39.14	+ 6	+ 91	- 8	23.26	+6	
	4		13.8063	25.5037	- 24	-1.4	-.5	40 41 18.46	- 4 55.46	+ 5	- 30	- 8	22.67	+6	α
	5		22.4617	18.5387	+ 12	-.6	-.3	40 38 2.86	- 1 39.14	+ 7	- 14	- 3	23.62	+6	21.6 α
	6		15.3773	29.4153	+198	+1.4	+ .9	40 42 18.20	- 5 55.16	+ 12	+ 35	-14	23.37	+5	
	7		22.1197	16.1687	- 32	-.6	-1.5	40 38 53.65	- 2 30.27	+ 5	- 29	- 4	23.10	+6	21.2
	8		15.5407	26.2110	+ 55	+ .4	+ .2	40 40 53.16	- 4 29.72	+ 7	+ 9	- 9	23.51	+6	21.0
	10		31.9743 ^{iv}	10.5440 ^u	+ 10	-.5	+1.0	40 27 20.15	+ 9 1.44	+ 93	+ 4	+15	22.71	+6	20.6
	IV 1		20.1190	22.9037	+ 27	-.7	-.5	40 35 12.76	+ 1 10.42	+ 8	- 18	+ 2	23.10	+5	
	2		26.7907	15.3800	+ 74	+ .5	-.3	40 41 11.92	- 4 48.47	+ 5	+ 4	- 8	23.46	+6	20.3
	3		12.2497 ^u	31.7953 ^{iv}	- 5	+ .4	+1.6	40 44 37.51	- 8 13.79	- 79	+ 27	-17	23.03	+5	
	4		12.5717 ^u	31.1833 ^{iv}	- 17	+ .8	+1.3	40 44 14.15	- 7 50.16	- 82	+ 30	-14	23.33	+5	19.9
	5		22.7950	18.7237	+ 19	-1.6	-.3	40 34 40.43	+ 1 42.91	+ 5	- 31	+ 3	23.11	+5	19.4
	VIII 1	R	22.7617	19.9903	+ 25	-2.3	-2.3	40 37 34.28	- 1 10.08	+ 6	- 68	- 2	23.56	-7	15.5
	2		13.9673	26.5440	+ 19	-1.7	-.5	40 31 5.50	+ 5 17.80	+ 11	- 35	+12	23.18	-6	
	3		14.0667	25.9720	- 0	-1.5	+ .5	40 41 24.32	- 5 0.77	+ 5	- 19	- 9	23.32	-7	α
	4		16.1380	24.8660	+ 26	+ .4	-.2	40 32 42.34	+ 3 40.58	+ 6	+ 4	+ 6	23.08	-7	
	5		31.4337 ^{iv}	11.3777 ^u	- 0	+ .8	+ .6	40 27 35.10	+ 8 26.72	+ 96	+ 21	+16	23.15	-7	
	6		19.9743	22.7113	+ 24	+ .1	+ .5	40 37 31.29	- 1 9.21	+ 7	+ 8	- 2	22.21	-7	
	7		14.1240 ^u	30.4230 ^{iv}	- 49	+1.3	-.6	40 29 30.23	+ 6 51.67	+ 93	+ 14	+12	23.09	-7	
	8		23.5360	22.5327	+ 19	+ .8	+2.5	40 35 56.69	+ 25.40	+ 10	+ 46	+ 1	22.66	-6	16.2
	9		28.7710	14.7037	+145	-2.5	-.4	40 30 27.56	+ 5 55.77	+ 9	- 47	+11	23.06	-7	15.9
	10		5.8317 ^u	33.2423 ^{iv}	- 21	-1.3	+ .3	40 47 56.97	-11 32.48	- 80	- 18	-23	23.28	-7	15.4
	11		29.4720	14.4183	+172	-2.0	-3.3	40 42 44.73	- 6 20.77	+ 4	- 76	-12	23.12	-7	
	IX 1		28.6237	12.6810	+ 61	-.5	-1.0	40 29 39.92	+ 6 42.94	+ 8	- 21	+13	22.86	-7	14.3
Dec. 28	III 1	D	16.1483	24.3770	+ 14	+ .3	+ .5	40 39 50.73	- 3 27.93	+ 5	+ 11	- 6	22.90	+6	22.4 δ
	2		2.9940 ^u	31.6793 ^{iv}	-136	-1.0	-.1	40 24 17.56	+12 4.38	+ 95	- 18	+21	22.92	+6	
	3		25.2567	14.2150	- 18	+1.7	+ .3	40 41 1.41	- 4 38.91	+ 6	+ 33	- 8	22.81	+6	20.9
	5		18.6593	22.6120	+ 16	-.2	-.2	40 38 2.82	- 1 39.90	+ 7	- 6	- 3	22.90	+6	
	6		25.4430	11.3667	-133	+ .5	-.1	40 42 18.17	- 5 55.30	+ 12	+ 7	-14	22.92	+5	20.2
	7		18.2230	24.1590	+ 41	-2.9	-1.3	40 38 53.62	- 2 30.08	+ 6	- 66	- 4	22.90	+6	19.6
	8		25.3013	14.6087	- 4	+ .8	+ .8	40 40 53.16	- 4 30.13	+ 7	+ 24	- 9	23.25	+6	
	9		14.2467	25.7783	0	-.8	-1.4	40 31 31.98	+ 4 51.34	+ 11	- 31	+11	23.23	+5	
	10		8.8283 ^u	30.2823 ^{iv}	- 3	-.9	-1.9	40 27 20.15	+ 9 2.01	+ 93	- 40	+15	22.84	+6	
	IV 1		21.8627	19.0807	+ 7	-.2	-.2	40 35 12.78	+ 1 10.30	+ 8	- 6	+ 2	23.12	+5	18.8
	2		15.0583	26.5040	+ 51	-1.2	+ .8	40 41 11.95	- 4 49.29	+ 5	- 10	- 8	22.53	+6	18.3
	3		30.3813 ^{iv}	10.8533 ^u	0	-.8	-.1	40 44 37.53	- 8 13.36	- 79	- 15	-17	23.06	+5	
	4		29.3737 ^{iv}	10.7757 ^u	- 1	+ .1	-.7	40 44 14.19	- 7 49.87	- 82	- 7	-14	23.29	+5	17.9
	5		19.3473	23.4040	+ 32	-.1	-.2	40 34 40.48	+ 1 42.57	+ 5	- 4	+ 3	23.09	+5	17.5
	6		16.3940	23.6553	+ 1	-.6	-2.2	40 39 27.00	- 3 3.45	+ 4	- 38	- 5	23.16	+5	
	7		6.3193 ^u	31.6793 ^{iv}	- 32	+1.2	+ .8	40 25 39.97	+10 40.63	+ 98	+ 31	+24	22.13	+4	
	8		12.9567	25.5387	- 56	+1.9	+3.8	40 41 39.99	- 5 17.74	+ 7	+ 81	-11	23.02	+4	
	9		25.8493	13.0393	- 45	+ .2	+ .2	40 30 59.60	+ 5 23.52	+ 8	- 6	+10	23.36	+4	16.7
	VIII 3	D	26.8190	14.9313	+ 61	-2.5	-3.6	40 41 24.19	- 5 0.49	+ 5	- 89	- 9	22.77	-7	13.0
	4		25.4100	16.6520	+ 52	-1.7	-1.1	40 32 42.18	+ 3 41.41	+ 6	- 43	+ 6	23.28	-7	11.9

1892	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Dec. 28	VIII 5	D	10.1300 ^{II}	30.2213 ^{IV}	0	— .7	— .9	40 27 34.96	+ 8 27.62	+ 96	— 23	+ 16	40 36 23.47	— 7	10.9
			21.6720	18.9803	+ 6	— 1.3	— 2.4	40 37 31.13	— 1 8.03	+ 7	— 53	— 2	22.62	— 7	
			28.3017 ^{IV}	11.9840 ^{II}	— 3	— 2.9	— 1.9	40 29 30.07	+ 6 52.27	+ 93	— 74	+ 12	22.65	— 7	
			11.1250	25.2353	— 153	— .7	— 2.3	40 30 27.39	+ 5 56.13	+ 9	— 42	+ 11	23.30	— 7	11.8
			29.3470 ^{IV}	1.8970 ^{II}	— 192	— .6	— .8	40 47 56.79	— 11 33.06	— 80	— 20	— 23	22.50	— 7	11.3
1893 Jan. 3	VIII 3	R	13.9483	29.0283	+ 132	— 1.6	— .5	40 42 44.52	— 6 21.34	+ 4	— 34	— 12	22.76	— 7	
			11.8000	27.7660	— 20	— 1.5	— 2.4	40 29 39.71	+ 6 43.35	+ 8	— 56	+ 13	22.71	— 7	10.6
			15.0147	26.8593	+ 62	— 1.6	— 1.8	40 41 23.33	— 4 59.41	+ 5	— 50	— 9	23.38	— 7	15.7
			16 3560	25.1847	+ 37	— 2.2	— 1.8	40 32 41.19	+ 3 41.89	+ 7	— 60	+ 6	22.61	— 7	
			32.6240 ^{IV}	12.5067 ^{II}	0	— .2	— .6	40 27 53.97	+ 8 28.26	+ 96	— 11	+ 16	23.24	— 7	
			19.9923	22.6327	+ 23	— 2.0	— .8	40 37 30.06	— 1 6.76	+ 7	— 44	— 2	22.91	— 7	
			11.6740 ^{II}	28.0240 ^{IV}	+ 3	— .8	— 1.1	40 29 28.93	+ 6 53.09	+ 93	— 27	+ 12	22.80	— 7	17.0
			21.9140	20.8097	+ 8	— 3.7	— 2.1	40 35 55.40	+ 27.92	+ 10	— 90	+ 1	22.53	— 7	
			27.8340	13.7160	+ 63	— .9	— .2	40 30 26.18	+ 5 56.85	+ 9	— 18	+ 11	23.05	— 7	17.0
			9.7310 ^{II}	37.0770 ^{IV}	+ 147	— .1	+ .2	40 47 55.50	— 11 31.26	— 80	+ 1	— 23	23.22	— 7	
			29.2703	14.2627	+ 156	— .2	— .8	40 42 43.12	— 6 19.56	+ 4	— 14	— 11	23.35	— 8	
			28.2030	12.2333	+ 20	— .2	0	40 29 38.30	+ 6 43.52	+ 8	— 3	+ 13	22.00	— 7	16.6
			25.4233	16.6127	+ 51	— 1.2	— 2.6	40 32 40.81	+ 3 42.73	+ 7	— 54	+ 6	23.13	— 7	16.4
			19.5947	16.9727	— 25	— 1.4	— 2.0	40 37 29.63	— 1 6.18	+ 7	— 50	— 2	23.00	— 7	16.0
			28.3637 ^{IV}	12.0083 ^{II}	— 4	0	— .2	40 29 28.38	+ 6 53.21	+ 93	— 2	+ 12	22.62	— 8	16.5
Jan. 13	III 6	R	19.4647	20.5967	0	— .8	— 2.0	40 35 54.91	+ 28.60	+ 10	— 40	+ 1	23.22	— 7	
			13.9393	28.9560	+ 125	+ .6	— .3	40 42 42.42	— 6 19.71	+ 4	+ 6	— 11	22.70	— 8	16.0
			15.2510	29.2470	+ 185	— .4	— 1.4	40 42 17.65	— 5 54.08	+ 11	— 25	— 10	23.33	+ 4	14.0
			22.9967	17.0877	+ 1	— 2.2	— 3.5	40 38 52.98	— 2 29.29	+ 6	— 82	— 4	22.89	+ 5	13.4
			16.2240	26.8410	+ 96	— .9	— 1.8	40 40 52.90	— 4 28.43	+ 7	— 38	— 8	24.03	+ 5	13.2
			31.9907 ^{IV}	10.5363 ^{II}	+ 12	— .6	— 1.5	40 27 20.01	+ 9 2.09	+ 94	— 30	+ 15	22.89	+ 5	
			19.7897	22.6060	+ 20	— 2.9	— 2.4	40 35 13.02	+ 1 11.21	+ 8	— 80	+ 2	23.53	+ 5	12.9
			25.4753	14.0427	— 16	— 1.0	— 2.7	40 41 12.31	— 4 48.81	+ 5	— 52	— 8	22.95	+ 5	
			10.8807 ^{II}	30.4633 ^{IV}	0	— .2	+ .2	40 44 38.09	— 8 14.77	— 79	— 1	— 17	22.35	+ 5	13.0
			10.3977 ^{II}	29.0047 ^{IV}	— 1	+ .8	+ .9	40 44 14.89	— 7 50.11	— 1.10	+ 25	— 14	23.79	+ 5	12.8
			23.0990	27.1157	+ 120	+ .3	+ 1.1	40 34 41.35	+ 1 41.78	+ 5	+ 19	+ 3	23.40	+ 5	
			23.3407	15.9843	— 13	+ 2.7	+ 1.5	40 39 27.99	— 3 5.83	+ 5	+ 65	— 5	22.81	+ 5	13.0
			28.3770	15.8753	+ 159	— 3.5	— 3.2	40 41 41.23	— 5 16.26	+ 7	— 1.01	— 11	23.92	+ 4	
			14.4763	27.2663	+ 68	— 3.2	— 3.9	40 31 0.95	+ 5 23.31	+ 8	— 1.05	+ 10	23.39	+ 4	
			10.0417 ^{II}	31.3917 ^{IV}	+ 5	— .5	— .9	40 27 23.63	+ 8 59.44	+ 95	— 20	+ 17	23.99	+ 4	13.0
Jan. 16	III 7	D	18.1587	24.0760	+ 40	— .2	+ .5	40 38 52.84	— 2 29.61	+ 6	+ 3	— 4	23.28	+ 5	10.6
			16.1487	27.6910	+ 132	— 2.2	— 3.5	40 31 31.88	+ 4 51.96	+ 11	— 82	+ 8	23.21	+ 5	10.0
			9.5723 ^{II}	31.0377 ^{IV}	+ 1	+ .2	— .3	40 27 19.95	+ 9 2.35	+ 94	0	+ 15	23.39	+ 5	
			21.0643	18.3043	— 5	+ 1.3	+ 2.8	40 35 13.05	+ 1 9.72	+ 9	+ 58	+ 2	23.46	+ 5	10.0
			15.2880	26.7350	+ 67	+ .4	0	40 41 12.35	— 4 49.39	+ 5	+ 7	— 8	23.00	+ 5	
			29.5930 ^{IV}	10.0457 ^{II}	0	— 1.1	— 2.0	40 44 38.19	— 8 13.89	— 79	— 45	— 17	22.89	+ 5	
			29.4220 ^{IV}	10.7980 ^{II}	— 1	+ 6	— 1.4	40 44 15.00	— 7 50.55	— 82	— 8	— 14	23.41	+ 5	10.0
			25.5547	21.5713	+ 84	— .3	+ .8	40 34 41.49	+ 1 40.86	+ 5	+ 5	+ 3	22.48	+ 5	
			4.9910 ^{II}	30.3413 ^{IV}	— 73	+ .4	+ 1.6	40 25 41.24	+ 10 40.32	+ 98	+ 27	+ 24	23.05	+ 4	
			15.0403	27.5943	+ 99	— 3.9	— 1.3	40 41 41.46	— 5 17.44	+ 7	— 83	— 11	23.15	+ 4	
			25.8537	13.1320	— 39	+ 2.3	+ 1.3	40 31 1.20	+ 5 21.33	+ 8	+ 56	+ 10	23.27	+ 4	
			29.9500 ^{IV}	8.6447 ^{II}	— 6	— 1.2	— .3	40 27 23.89	+ 8 58.29	+ 95	— 24	+ 17	23.06	+ 4	9.4
			22.8370	16.8870	— 5	+ 2.6	+ 1.8	40 38 52.78	— 2 30.32	+ 5	+ 67	— 4	23.14	+ 5	13.5
			16.2907	26.9267	+ 100	— .6	— .9	40 40 52.81	— 4 28.97	+ 7	— 21	— 8	23.62	+ 5	13.2
			26.1460	14.6260	+ 26	+ .9	+ .7	40 31 31.87	+ 4 51.13	+ 11	+ 24	+ 8	23.43	+ 5	
Jan. 17	IV 10	R	32.2473 ^{IV}	10.7777 ^{II}	+ 12	— 2.8	— 3.1	40 27 19.94	+ 9 2.48	+ 94	— 87	+ 15	22.64	+ 5	
			19.5190	22.2853	+ 14	0	+ .4	40 35 13.06	+ 1 9.93	+ 8	+ 5	+ 2	23.14	+ 5	12.4
			26.8300	15.3927	+ 75	— 1.6	+ .8	40 41 12.36	— 4 49.16	+ 5	+ 38	— 8	23.55	+ 5	
			10.8207 ^{II}	30.3633 ^{IV}	0	— 2.5	— 1.3	40 44 38.23	— 8 13.76	— 89	— 60	— 17	22.81	+ 5	
			11.7530 ^{II}	30.4087 ^{IV}	— 9	— .1	+ .8	40 44 15.05	— 7 51.32	— 82	+ 9	— 14	22.86	+ 5	11.9

1895	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Jan. 17	IV 5	D	21.7570	17.7357	— 6	—1.1	— .2	40 34 41.55	+ 1 41.58	+	5	— 21	+ 3	40 36 23.00	+5 11.7
			23.6953	16.3467	0	+4.9	+4.4	40 39 28.22	— 3 5.66	+	5	+1.40	— 5	23.96	+5 11.6
			28.7980	16.2130	+186	+ .4	+ .7	40 41 41.55	— 5 18.44	+	7	+ 16	—11	23.23	+4 11.4
			15.1907	27.9213	+118	+1.1	+ .4	40 31 1.30	+ 5 21.95	+	8	+ 24	+10	23.67	+4 11.3
			10.8440 ^{II}	31.6487 ^{IV}	+ 7	+ .2	— .6	40 27 24.00	+ 8 58.30	+	95	— 4	+17	23.38	+4
Jan. 19	VIII 6	R	20.3207	22.9077	+ 24	—1.3	—2.0	40 37 28.61	— 1 5.43	+	7	— 48	— 2	22.76	—7 15.8
			13.0997 ^{II}	29.5257 ^{IV}	— 27	— .9	—2.0	40 29 27.28	+ 6 54.94	+	93	— 41	+12	22.86	—8 15.6
			23.8653	22.7310	+ 22	+ .8	+ .4	40 35 53.71	+ 28.72	+	10	+ 18	+ 1	22.72	—7 15.4
			4.5483 ^{II}	31.8480 ^{IV}	— 79	— .7	— .4	40 47 53.38	—11 29.53	—	80	— 17	—23	22.65	—7 15.2
			30.1233	15.2220	+235	— .7	— .9	40 42 40.73	— 6 17.08	+	4	— 23	—11	23.35	—8
	IX 1		29.6023	13.4767	+146	—1.2	—1.0	40 29 35.75	+ 6 47.79	+	8	— 33	+13	23.42	—8 15.2
			25.3593	18.0570	+ 75	+2.6	+2.3	40 39 27.04	— 3 4.68	+	5	+ 74	— 5	23.10	—8
			16.9310	22.9163	— 4	— .5	— .6	40 38 54.30	— 2 31.21	+	5	— 16	— 4	22.94	—8 15.2
			20.3867	22.0330	+ 12	+ .6	+1.3	40 35 40.77	+ 41.63	+	6	+ 27	+ 2	22.75	—8 15.3
			20.4990	23.3693	+ 33	—1.1	— .3	40 37 35.40	— 1 12.61	+	7	— 23	— 2	22.61	—8 15.4
Jan. 20	VIII 9	D	22.1063	21.0553	+ 10	— .9	—1.8	40 36 49.70	— 26.58	+	9	— 38	— 1	22.82	—7 15.5
			12.5550	26.7510	— 30	+ .7	+ .6	40 30 24.21	+ 5 58.59	+	9	+ 19	+11	23.19	—7 13.6
			31.7257 ^{IV}	4.4343 ^{II}	— 84	+ .6	— .3	40 47 53.31	—11 29.31	—	80	+ 6	—23	23.03	—7
			13.3713	28.2967	+ 74	— .8	— .4	40 42 40.63	— 6 17.28	+	4	— 18	—11	23.10	—8 14.5
			11.7923	27.9093	— 15	—3.6	—2.5	40 29 35.64	+ 6 47.16	+	8	— 94	+13	22.07	—8 14.9
Jan. 21	IX 1		17.0890	24.3517	+ 32	—2.4	—2.5	40 39 26.90	— 3 3.57	+	5	— 73	— 5	22.60	—8
			21.7683	15.7853	— 42	+ .1	— .8	40 38 54.14	— 2 31.05	+	5	— 9	— 4	23.01	—8 15.0
			21.1623	18.2900	— 5	— .8	— .8	40 37 35.23	— 1 12.56	+	7	— 24	— 2	22.48	—8
			18.1353	19.2207	— 8	0	+ .8	40 36 49.51	— 27.41	+	9	+ 10	— 1	22.28	—7 14.4
			21.2953	18.5160	— 2	0	+ .3	40 35 12.96	+ 1 10.21	+	9	+ 4	+ 2	23.32	+5 21.0
	IV 1	D	14.2420	25.7097	— 3	0	+ .6	40 41 12.29	— 4 49.72	+	1	+ 7	— 8	22.57	+5 20.0
			28.6263 ^{IV}	9.0660 ^{II}	+ 3	0	— .4	40 44 38.23	— 8 14.19	—	85	— 5	—17	22.97	+5
			29.7127 ^{IV}	11.0670 ^{II}	— 3	0	—1.2	40 44 15.09	— 7 51.07	—	88	— 15	—14	22.85	+5
			20.6860	24.6810	+ 64	— .6	—1.1	40 34 41.67	+ 1 41.09	+	6	— 24	+ 3	22.61	+5 20.0
			16.7987	24.1420	+ 20	— .8	—2.2	40 39 28.37	— 3 5.58	+	3	— 42	— 5	22.35	+5
	V 1		6.4533 ^{II}	31.7653 ^{IV}	— 28	+1.0	+1.4	40 25 41.53	+10 39.43	+1.07	+	35	+24	22.62	+4
			14.2330	26.8333	+ 37	—2.8	—1.0	40 41 41.82	— 5 18.43	+	3	— 60	—11	22.71	+4
			25.6670	12.9473	— 52	—2.0	—2.8	40 31 1.60	+ 5 21.22	+ 12	—	70	+10	22.34	+4 19.5
			31.7440 ^{IV}	10.4417 ^{II}	+ 9	—1.6	—2.3	40 27 24.34	+ 8 58.22	+1.02	—	57	+17	23.18	+4 17.1
			13.1577	28.9080	+ 95	—1.0	—2.2	40 29 44.81	+ 6 38.17	+	13	— 45	+11	22.77	+4 17.0
Jan. 23	IV 1	D	22.3887	18.5837	+ 12	— .2	— .5	40 38 24.16	— 2 1.42	+	4	— 10	— 4	22.64	+3
			31.6363 ^{IV}	8.2097 ^{II}	— 2	—1.1	—1.1	40 26 30.10	+ 9 51.86	+1.09	—	33	+24	22.96	+3
			27.5303	12.8060	+ 14	0	0	40 42 35.00	— 6 12.04	+	1	— 0	—12	22.85	+3
			6.8060 ^{II}	30.1760 ^{IV}	— 30	—3.0	—3.5	40 26 32.96	+ 9 50.36	+1.04	—	96	+19	23.59	+3 16.9
			19.9850	21.2703	+ 5	— .5	—1.9	40 36 54.72	— 32.49	+	12	— 33	— 1	22.01	+2 16.4
	VIII 8	R	27.8593	12.7413	+ 27	+ .4	—2.1	40 42 45.33	— 6 22.02	+	2	— 20	—13	23.00	+2
			22.1467	17.8430	— 1	—2.0	—2.1	40 34 34.74	+ 1 48.73	+	9	— 61	+ 4	22.99	+2
			27.9360	13.7890	+ 70	—1.8	—2.5	40 42 21.59	— 5 57.60	—	0	— 63	—10	23.26	+2
			18.5333	21.9953	+ 5	— .2	— .7	40 37 50.50	— 1 27.48	+	6	— 12	— 3	22.93	+1 16.4
			19.4117	22.2067	+ 13	—1.1	+ .3	40 35 12.82	+ 1 10.64	+	9	— 15	+ 2	23.42	+4 22.4
Jan. 25	IV 1	D	27.3140	15.9143	+108	— .8	—2.2	40 41 12.15	— 4 48.28	+	1	— 42	— 8	23.38	+5
			12.7840 ^{II}	32.3377 ^{IV}	— 9	—2.1	—2.4	40 44 38.15	— 8 13.98	—	85	— 67	—17	22.48	+4 22.7
			10.6033 ^{II}	29.2373 ^{IV}	— 1	+ .2	+1.0	40 44 15.02	— 7 50.77	—	88	+ 16	—14	23.39	+5 21.9
			26.2417	22.2150	+101	—1.2	—1.6	40 34 41.62	+ 1 41.99	+	7	— 41	+ 3	23.30	+5
			34.0010 ^{IV}	8.6357 ^{II}	+ 41	—3.3	—3.8	40 25 41.53	+10 40.93	+1.07	—1.05	+24		22.72	+4 21.4
	VIII 8	R	28.1407	15.5667	+137	—2.0	—2.7	40 41 41.84	— 5 18.01	+	3	— 69	—11	23.06	+4
			15.1527	27.8750	+115	—1.0	—1.6	40 31 1.65	+ 5 21.70	+	12	— 37	+10	23.20	+4 21.3
			8.8033 ^{II}	30.0993 ^{IV}	— 4	+ .9	+ .2	40 27 24.41	+ 8 58.01	+1.02	+	18	+17	23.79	+4 21.4
			21.0810	18.3163	— 5	+ .9	+2.2	40 35 12.68	+ 1 9.83	+	9	+ 44	+ 2	23.06	+4 35.1
			14.1090	25.5707	— 10	+ .6	+1.8	40 41 12.03	— 4 49.53	+	1	+ 33	— 8	22.76	+5

1893	Patr	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Jan. 25	IV	3 D	29.6773 ^{iv}	10.1157 ⁱⁱ	0	— .4	—1.4	40 44 38.05	— 8 14.17	— 85	— 25	—17	40 36 22.61	+4	33.9
		4	29.2713 ^{iv}	10.6127 ⁱⁱ	— 1	— .2	— .8	40 44 14.94	— 7 51.86	— 88	— 14	—14	22.42	+5	33.4
		5 R	19.8873	23.8797	+ 45	+ .4	—1.1	40 34 41.56	+ 1 40.97	+ 7	— 7	+ 3	22.56	+5	
		6 D	13.7193	21.0650	—115	+ .6	—1.3	40 39 28.29	— 3 5.28	+ 3	— 7	— 5	22.92	+5	
		7 R	33.6347 ^{iv}	8.2857 ⁱⁱ	+ 30	—1.9	—2.4	40 25 41.52	+10 40.45	+1.07	— 63	+24	22.65	+4	32.9
		8 D	13.1120	25.7247	— 45	— .5	—1.3	40 41 41.85	— 5 18.51	+ 3	— 25	—11	23.01	+4	32.8
		9	27.0453	14.3257	+ 50	— .9	— .9	40 31 1.67	+ 5 21.45	+ 12	— 27	+10	23.07	+4	31.5
	V	10	32.5433 ^{iv}	11.2580 ⁱⁱ	+ 15	—1.3	—1.1	40 27 24.44	+ 8 57.76	+1.02	— 36	+17	23.03	+4	
		1	15.6310	31.3680	+326	—1.0	—1.5	40 29 44.93	+ 6 38.38	+ 13	— 36	+11	23.19	+4	31.0
		2 R	18.7130	23.4827	+ 32	—2.7	—2.0	40 38 24.32	— 2 0.57	+ 4	— 72	— 4	23.03	+4	30.5
		3	10.4677 ⁱⁱ	33.9173 ^{iv}	+ 43	— .9	—2.8	40 26 30.28	+ 9 52.50	+1.09	— 51	+24	23.60	+3	
		4	13.0760	27.7820	+ 40	—1.9	—2.5	40 42 35.22	— 6 11.61	+ 1	— 65	—12	22.85	+3	
		5	32.5227 ^{iv}	9.1763 ⁱⁱ	+ 16	—2.9	—1.8	40 26 33.19	+ 9 49.82	+1.04	— 72	+19	23.52	+3	30.1
		6	22.4213	21.1563	+ 14	—1.7	—1.3	40 36 54.96	— 31.99	+ 12	— 46	— 1	22.62	+2	29.4
		7	13.1880	28.3250	+ 68	— .8	—1.1	40 42 45.61	— 6 22.57	+ 2	— 27	—13	22.66	+2	29.2
	IV	8	20.0267	24.3103	+ 55	—2.1	—3.2	40 34 35.05	+ 1 48.35	+ 9	— 77	+ 4	22.76	+2	
		9	14.0110	28.1777	+ 92	—1.8	—2.0	40 42 21.93	— 5 58.12	0	— 56	—10	23.15	+2	
		10	24.2056	20.7810	+ 50	— .8	— .9	40 37 50.84	— 1 26.64	+ 6	— 25	— 3	23.98	+2	28.5
		1 R	19.2053	21.9907	+ 10	+ .9	+ .8	40 35 12.63	+ 1 10.39	+ 9	+ 26	+ 2	23.39	+4	35.0
		2	25.9247	14.5327	+ 12	—1.3	—2.1	40 41 11.97	— 4 47.82	+ 1	— 49	— 8	23.59	+5	
		3	12.0247 ⁱⁱ	31.5887 ^{iv}	— 5	+ .5	+ .5	40 44 38.02	— 8 14.22	— 85	+ 15	—17	22.93	+4	
		4	11.7940 ⁱⁱ	30.4253 ^{iv}	— 10	—1.7	— .3	40 44 14.91	— 7 50.64	— 88	— 33	—14	22.92	+5	34.5
	D	5	25.5883	21.6133	+ 85	+3.0	+1.5	40 34 41.54	+ 1 40.63	+ 7	+ 70	+ 3	22.97	+5	
		6 R	23.4523	16.0623	— 10	+4.2	+3.6	40 39 28.28	— 3 6.66	+ 3	+1.18	— 5	22.98	+5	
		7	33.2347 ^{iv}	7.9040 ⁱⁱ	+ 17	— .7	+ .2	40 25 41.52	+10 39.95	+1.07	— 9	+24	22.69	+4	
		8	27.9287	15.3530	+122	— .6	— .8	40 41 41.86	— 5 18.00	+ 3	— 20	—11	23.58	+4	
		10	8.9470 ⁱⁱ	30.2343 ^{iv}	— 2	— .2	— .2	40 27 24.46	+ 8 57.76	+1.02	— 6	+17	23.35	+4	33.4
		1	28.8470	13.0970	+ 90	— .1	—1.6	40 29 44.96	+ 6 38.11	+ 13	— 22	+11	23.09	+4	
		2	18.4637	23.2417	+ 24	—2.0	—1.8	40 38 24.36	— 2 0.76	+ 4	— 57	— 4	23.03	+4	31.6
	V	3	10.2647 ⁱⁱ	33.7010 ^{iv}	+ 40	—2.2	—2.3	40 26 30.32	+ 9 52.15	+1.09	— 67	+24	23.13	+3	31.2
		4	13.9177	28.6317	+110	— .4	— .2	40 42 35.26	— 6 11.99	+ 1	— 9	—12	23.07	+3	
		5	31.4497 ^{iv}	8.0943 ⁱⁱ	— 4	—2.5	—1.2	40 26 33.24	+ 9 50.00	+1.04	— 58	+19	23.89	+3	
		6	21.9147	20.6853	+ 9	—2.4	—3.1	40 36 55.00	— 31.08	+ 12	— 81	— 1	23.22	+2	30.4
		7	12.7787	27.9043	+ 31	—1.8	—1.7	40 42 45.66	— 6 22.19	+ 2	— 52	—13	22.84	+2	30.0
		8	19.6220	23.8993	+ 44	—1.0	—1.8	40 34 35.11	+ 1 48.16	+ 9	— 40	+ 4	23.00	+2	
		9	13.2710	27.4623	+ 31	—2.0	—1.6	40 42 22.00	— 5 58.58	0	— 54	—10	22.78	+2	
	IX	10	22.7943	19.3463	+ 22	—2.3	—1.8	40 37 50.91	— 1 27.16	+ 6	— 62	— 3	23.16	+2	30.5
		1 R	28.1327	11.9563	+ 5	—2.0	—3.1	40 29 34.49	+ 6 48.69	+ 14	— 74	+13	22.71	—8	22.6
		2	24.4433	17.2520	+ 35	— .9	— .6	40 39 25.30	— 3 1.77	+ 3	— 23	— 5	23.28	—9	
		3	17.7793	23.6867	+ 26	— .9	— .5	40 38 52.42	— 2 29.31	+ 4	— 22	— 4	22.89	—9	21.6
		4	19.8113	21.5977	+ 6	—1.3	—2.0	40 35 38.63	+ 45.15	+ 7	— 48	+ 2	23.39	—9	
		5	20.9707	23.7515	+ 40	+ .2	— .5	40 37 33.24	— 1 10.35	+ 6	— 3	— 2	22.90	—8	21.5
		6	21.8020	20.8523	+ 7	—1.8	—1.3	40 36 47.41	— 24.01	+ 9	— 47	— 1	23.01	—8	
	X	7	8.4650 ⁱⁱ	31.9930 ^{iv}	+ 5	—2.0	—2.6	40 46 17.89	— 9 54.42	— 90	— 67	—17	21.73	—9	
		1	27.4873	15.2263	+100	—1.4	—2.1	40 41 38.17	— 5 10.01	+ 1	— 51	— 9	22.57	—9	20.3
		2	32.6383 ^{iv}	12.2980 ⁱⁱ	+ 3	+ .4	—1.4	40 27 48.37	+ 8 33.89	+1.03	+ 11	+17	23.35	—8	21.1
		3	21.6047	18.6603	+ 3	+ .7	+ .2	40 35 8.63	+ 1 14.39	+ 7	+ 14	+ 2	23.25	—9	19.8
		3 D	29.3050 ^{iv}	9.8063 ⁱⁱ	— 1	—3.2	—4.5	40 44 37.82	— 8 12.63	— 85	—1.12	—17	23.05	+4	18.2
		4	29.0217 ^{iv}	10.4233 ⁱⁱ	+ 2	—2.5	—2.4	40 44 14.76	— 7 49.90	— 88	— 73	—14	23.11	+4	17.6
		5 R	17.5200	21.5137	— 13	0	— .4	40 34 41.52	+ 1 40.87	+ 7	— 5	+ 3	22.44	+4	17.3
Feb. 4	IV	6 D	16.0067	23.3610	— 12	— .2	+ .6	40 39 28.33	— 3 5.78	+ 3	+ 4	— 5	22.57	+4	
		7	4.8060 ⁱⁱ	30.0850 ^{iv}	— 80	+1.7	+2.3	40 25 41.74	+10 38.47	+1.07	+ 58	+24	22.10	+4	
		8	14.0607	26.7093	+ 29	+ .1	+ .9	40 41 42.19	— 5 19.64	+ 3	+ 13	—11	22.60	+4	17.2
		9	28.3160	15.6383	+147	— .8	— .5	40 31 2.10	+ 5 20.68	+ 12	— 20	+10	22.80	+4	
		10	30.4320 ^{iv}	9.1690 ⁱⁱ	— 2	— .2	+ .7	40 27 24.95	+ 8 57.20	+1.02	+ 5	+17	23.39	+4	

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude		Δ	Ther.
						A	B		Micrometer	δ	l	r				
Feb.																
4	V	1	13.5540	29.2623	+130	+ .1	+ .9	40 29 45.49	+ 6 37.20	+ 13	+ 13	+11	40 36 23.06	+4	16.1	
		2	23.5250	18.6633	+ 32	+2.6	+3.0	40 38 25.01	- 2 2.91	+ 4	+ 83	- 4	22.93	+4	16.2	
		3	29.6113 ^{iv}	6.2623 ⁱⁱ	- 40	+1.2	+2.6	40 26 31.03	+ 9 49.81	+1.09	+ 54	+24	22.71	+3		
		4	27.7517	12.9667	+ 33	+1.1	+1.7	40 42 36.03	- 6 13.63	+ 1	+ 41	-12	22.70	+3		
		5	8.3877 ⁱⁱ	31.6563 ^{iv}	+ 1	+ .4	0	40 26 34.04	+ 9 47.88	+1.04	+ 7	+19	23.22	+3	16.2	
		6	19.2107	20.5457	- 1	+2.0	+1.8	40 36 55.85	- 33.73	+ 12	+ 57	- 1	22.80	+2		
		7	26.7983	11.6107	- 72	-1.3	- .3	40 42 46.57	- 6 23.53	+ 2	- 26	-13	22.67	+2	16.2	
		8	21.6960	17.4847	- 11	+1.0	+1.0	40 34 36.07	+ 1 46.37	+ 9	+ 30	+ 4	22.87	+2		
		9	28.4450	14.1523	+110	+1.4	+2.5	40 42 23.06	- 6 1.37	0	+ 56	-10	22.15	+2		
		10	14.9767	18.5687	- 69	+2.3	+3.2	40 37 51.97	- 1 30.58	+ 5	+ 80	- 3	22.21	+2	15.0	
	IX	1 D	12.2593	28.4280	+ 33	+ .7	+ .4	40 29 34.49	+ 6 48.63	+ 14	+ 17	+13	23.56	-8	9.4	
		2	16.0597	23.2403	- 15	-2.3	-1.7	40 39 25.26	- 3 1.39	+ 3	- 61	- 5	23.24	-9		
		3	22.1013	16.2093	- 30	- .8	- .8	40 38 52.37	- 2 28.79	+ 4	- 24	- 4	23.34	-9	10.4	
		4	21.2483	19.5007	+ 4	- .7	0	40 35 38.57	+ 44.16	+ 7	- 12	+ 2	22.70	-9		
		5	21.0953	18.3337	- 5	-1.1	- .2	40 37 33.16	- 1 9.77	+ 6	- 21	- 2	23.22	-8		
		6	19.4767	20.4150	+ 1	-2.2	-2.7	40 36 47.33	- 23.71	+ 9	- 72	- 1	22.98	-8		
		7	32.4927 ^{iv}	8.9647 ⁱⁱ	+ 16	+2.1	+1.1	40 46 17.78	- 9 54.50	- 90	+ 50	-17	22.71	-9	10.6	
	X	1	13.7760	26.0483	- 7	- .4	+ .8	40 41 33.06	- 5 10.06	+ 1	+ 3	- 9	22.95	-9	10.3	
		3	19.2080	22.1943	+ 12	-1.7	-3.0	40 35 8.50	+ 1 15.48	+ 7	- 67	+ 2	23.40	-9	9.5	
		4	10.2317 ⁱⁱ	25.7737 ^{iv}	+ 51	-2.8	-3.1	40 29 50.11	+ 6 32.82	+1.00	- 87	+11	23.17	-9		
Feb.																
8	IV	5 D	25.9697	21.9030	+ 94	- .8	-1.9	40 34 41.21	+ 1 42.98	+ 7	- 38	+ 3	23.91	+4	23.5	
		6 R	24.0167	16.7027	+ 14	0	+ .4	40 39 23.06	- 3 4.82	+ 3	+ 5	- 5	23.27	+4		
		7	33.0930 ^{iv}	7.6940 ⁱⁱ	+ 12	-5.9	-5.4	40 25 41.56	+10 41.71	+1.07	-1.70	+24	22.88	+3		
		8	27.2680	14.6607	+ 73	+ .3	- .3	40 41 42.04	- 5 18.69	+ 3	+ 1	-11	23.28	+4	23.4	
		9	14.6763	27.4040	+ 79	- .1	-1.0	40 31 2.00	+ 5 21.75	+ 12	- 14	+10	23.83	+4		
		10	11.3553 ⁱⁱ	32.6403 ^{iv}	+ 15	- .4	+ .2	40 27 24.89	+ 8 57.78	+1.02	- 4	+17	23.82	+4		
	V	1	28.9207	13.2000	+ 98	-1.9	-1.1	40 29 45.45	+ 6 37.42	+ 13	- 46	+11	22.65	+4		
		2	18.2917	23.1163	+ 20	-1.5	-1.7	40 38 25.03	- 2 1.94	+ 4	- 47	- 4	22.62	+4	22.4	
		4	14.4863	29.2133	+160	0	- .5	40 42 36.11	- 6 12.46	+ 1	- 7	-12	23.47	+3	21.4	
		5	32.5750 ^{iv}	9.1757 ⁱⁱ	+ 18	- .8	- .2	40 26 34.14	+ 9 48.68	+1.04	- 16	+19	23.89	+3		
		6	21.3487	20.0540	+ 5	-3.8	-3.3	40 36 56.00	- 32.73	+ 12	-1.07	- 1	22.31	+2	21.4	
		7	13.6877	28.8563	+114	-2.0	- .9	40 42 46.75	- 6 23.50	+ 2	- 45	-13	22.69	+3	20.4	
		8	19.4137	23.6513	+ 39	+ .8	- .9	40 34 36.28	+ 1 47.16	+ 9	+ 2	+ 4	23.59	+2	20.4	
		9	13.7503	27.9873	+ 73	-1.7	-1.3	40 42 23.32	- 5 59.87	0	- 46	-10	22.89	+2		
		10	23.4943	19.9990	+ 37	-3.1	-2.6	40 37 52.23	- 1 23.39	+ 6	- 86	- 3	23.01	+2	20.4	
Feb.																
11	IX	1 R	29.0157	12.8837	+ 90	+1.0	+ .6	40 29 34.43	+ 6 47.78	+ 14	+ 24	+13	22.72	-8	25.9	
		2	23.9333	16.6923	+ 12	+5.2	+4.1	40 39 25.04	- 3 2.97	+ 3	+1.41	- 5	23.46	-9		
		3	17.5740	23.5037	+ 19	+2.4	+2.5	40 38 52.09	- 2 29.85	+ 4	+ 73	- 4	22.97	-9		
		4	19.9993	21.7587	+ 9	+ .5	+1.3	40 35 38.19	+ 44.47	+ 7	+ 25	+ 2	23.00	-9	25.9	
		5	20.2013	22.9553	+ 28	+ .6	+ .8	40 37 32.74	- 1 9.65	+ 6	+ 20	- 2	23.33	-8		
		6	22.6480	21.6907	+ 12	- .2	- .3	40 36 46.84	- 24.21	+ 9	- 7	- 1	22.64	-8		
		7	9.3390 ⁱⁱ	32.8047 ^{iv}	+ 22	- .2	0	40 46 17.22	- 9 52.88	- 90	- 3	-17	23.24	-9		
	X	1	27.7123	15.4867	+116	- .6	-1.4	40 41 32.39	- 5 9.16	+ 1	- 28	- 9	22.87	-9	25.3	
		2	32.4233 ^{iv}	12.0673 ⁱⁱ	+ 7	+ .5	+2.1	40 27 47.58	+ 8 34.28	+1.03	+ 35	+17	23.41	-8		
		3	22.6990	19.6973	+ 23	-1.7	-1.4	40 35 7.74	+ 1 15.89	+ 7	- 47	+ 2	23.25	-9		
		4	29.3170 ^{iv}	13.7620 ⁱⁱ	- 41	+ .6	- .1	40 29 49.30	+ 6 32.87	+1.00	+ 8	+11	23.36	-9		
		5	11.5110 ⁱⁱ	32.2990 ^{iv}	+ 11	- .8	+ .1	40 45 69.18	- 8 45.21	- 84	- 12	-20	22.81	-8	24.8	
Feb.																
14	IV	7 D	6.5170 ⁱⁱ	31.8277 ^{iv}	- 27	+3.0	+4.7	40 25 41.51	+10 39.32	+1.07	+1.11	+24	23.25	+3	36.7a	
		8	12.3573	25.0070	- 97	+2.1	+1.2	40 41 42.05	- 5 19.30	+ 3	+ 51	-11	23.18	+4	35.6	
		9	26.8137	14.1383	+ 35	+1.8	+1.2	40 31 2.05	+ 5 20.29	+ 12	+ 46	+10	23.02	+4	34.9	
		10	32.9030 ^{iv}	11.6937 ⁱⁱ	+ 16	+1.5	+2.1	40 27 25.00	+ 8 55.82	+1.02	+ 52	+17	22.53	+4		
	V	1	14.3920	30.0590	+205	+1.6	+1.6	40 29 45.58	+ 6 36.29	+ 13	+ 48	+11	22.59	+4	34.9	
		2	23.3443	18.4970	+ 27	+ .4	+ .4	40 38 25.24	- 2 2.52	+ 4	+ 12	- 4	22.84	+4		
		3	31.2530 ^{iv}	7.8800 ⁱⁱ	- 9	+ .1	-1.4	40 26 31.36	+ 9 50.41	+1.09	- 16	+24	22.94	+3	34.6	
		4	28.1933	13.4490	+ 72	+1.0	+ .1	40 42 36.41	- 6 12.65	+ 1	+ 18	-12	23.83	+3		

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Feb. 14	V	5 D	8.8837 ^{II}	32.1343 ^{IV}	+ 9	+ .8	+1.6	40 26 34.47	+ 9 47.37	+1.04	+ 34	+19	40 36 23.41	+3	34.2
			19.6917	21.0487	0	+1.4	+1.9	40 36 56.33	— 34.28	+ 12	+ 48	— 1	22.69	+3	34.3
			27.8197	12.6137	+ 18	+ .5	+ .3	40 42 47.17	— 6 24.17	+ 2	+ 12	—13	23.01	+3	33.4
			24.5803	20.3940	+ 59	+ .2	+ .5	40 34 36.75	+ 1 45.91	+ 9	+ 10	+ 4	22.89	+2	
			30.6447	16.3943	+296	0	— .2	40 42 23.84	— 6 0.74	0	— 2	—10	22.98	+3	
Feb. 15	VI	1 R	21.2217	24.7803	+ 65	+2.2	+1.8	40 37 52.77	— 1 30.06	+ 5	+ 60	— 3	23.33	+2	33.2
			28.7187	13.0527	+ 82	+2.4	+2.5	40 29 45.62	+ 6 35.94	+ 13	+ 73	+11	22.53	+4	43.8
			18.7917	23.6767	+ 37	+2.2	+2.8	40 38 25.25	— 2 3.49	+ 4	+ 73	— 4	22.49	+3	43.1
			14.3817	29.1473	+154	+ .9	+2.3	40 42 36.43	— 6 13.37	+ 1	+ 45	—12	23.45	+3	
			33.2690 ^{IV}	10.0053 ^{II}	+ 34	—1.5	— .8	40 26 34.55	+ 9 47.73	+1.04	— 36	+19	23.15	+3	
		2	22.2247	20.8870	+ 12	+1.2	+ .3	40 36 56.43	— 33.82	+ 12	+ 24	— 1	23.01	+3	43.1
			13.2613	28.4960	+ 79	+1.5	+2.2	40 42 47.27	— 6 25.03	+ 2	+ 54	—13	22.67	+3	42.5
			19.9403	24.1350	+ 50	— .3	— .2	40 34 36.85	+ 1 46.08	+ 9	+ 7	+ 4	22.99	+2	
			14.8610	29.1597	+170	+1.4	+1.0	40 42 23.96	— 6 1.62	0	+ 37	—10	22.61	+3	42.5
			11.5330	27.6850	— 37	+1.0	0	40 29 34.39	+ 6 47.92	+ 14	+ 17	+13	22.75	—8	38.6
	IX	1 D	16.3617	23.5427	— 2	— .4	—1.6	40 39 24.88	— 3 1.89	+ 3	— 27	— 5	23.20	—8	38.4
			22.2520	16.3820	— 23	+ .3	+ .2	40 38 51.90	— 2 28.23	+ 4	+ 7	— 4	23.74	—8	37.8
			20.6230	18.8373	— 2	— .6	— .3	40 35 37.91	+ 45.10	+ 7	— 14	+ 2	22.96	—9	37.8
			20.5897	17.8287	— 13	— .8	—1.1	40 37 32.43	— 1 9.71	+ 6	+ 27	— 2	22.49	—8	
			12.8333	25.0670	— 76	—1.6	—2.0	40 41 31.94	— 5 8.85	+ 1	— 53	— 9	22.48	—9	37.3
	X	2	9.2187 ^{II}	29.6240 ^{IV}	0	—1.2	—1.4	40 27 47 11	+ 8 35.46	+1.03	— 38	+17	23.39	—8	
			18.8747	21.9240	+ 7	— .7	—1.2	40 35 7.22	+ 1 17.04	+ 7	— 27	+ 2	24.08	—9	
			11.6780 ^{II}	27.2440 ^{IV}	+ 15	+ .2	— .7	40 29 48.74	+ 6 33.25	+1.00	— 5	+11	23.05	—9	
			28.1173 ^{IV}	7.3623 ^{II}	— 10	0	— .8	40 45 8.65	— 8 44.27	— 84	— 10	—20	23.24	—8	
			21.3340	16.7070	— 28	— .8	—1.6	40 34 26.28	+ 1 56.82	+ 9	— 34	+ 4	22.89	—8	36.7
Feb. 16	IX	2 R	23.7177	16.5097	+ 4	+2.5	+2.4	40 39 24.88	— 3 2.11	+ 3	+ 73	— 5	23.48	—8	25.0
			16.5867	22.4917	— 16	+1.1	+1.8	40 38 51.90	— 29.14	+ 4	+ 42	— 4	23.18	—8	25.0
			19.5460	21.2667	+ 4	+2.0	+2.5	40 35 37.89	+ 43.43	+ 7	+ 66	+ 2	22.12	—9	24.4
			19.0867	21.8707	+ 8	+ .5	+2.6	40 37 32.40	— 1 10.35	+ 6	+ 42	— 2	22.51	—8	24.0
			21.6343	20.6843	+ 8	+ .9	+ .5	40 36 46.44	— 24.02	+ 9	+ 22	— 1	22.72	—8	
	X	7	7.4790 ^{II}	30.9450 ^{IV}	— 17	+ .6	+2.2	40 46 16.79	— 9 52.79	— 89	+ 38	—17	23.32	—9	
			26.7107	14.4337	+ 40	+2.0	+3.3	40 41 31.87	— 5 10.26	+ 1	+ 76	— 9	22.29	—9	23.7
			22.7013	19.7043	+ 21	+2.6	+4.2	40 35 7.13	+ 1 15.77	+ 7	+ 98	+ 2	23.97	—9	23.5
			30.1147 ^{IV}	14.5907 ^{II}	— 63	+3.1	+4.5	40 29 48.65	+ 6 32.03	+ 99	+1.11	+41	22.89	—9	
			18.6770	23.2500	+ 28	+1.1	+1.2	40 34 26.16	+ 1 55.60	+ 9	+ 34	+ 4	22.23	—8	23.4
Feb. 20	V	1 D	12.0183	27.7407	— 10	+ .7	0	40 29 45.54	+ 6 37.20	+ 17	+ 12	+11	23.14	+4	16.5
			23.1290	18.2847	+ 21	— .7	—1.4	40 38 25.30	— 2 2.45	+ 3	— 30	— 4	22.54	+3	
			31.6903 ^{IV}	8.3263 ^{II}	0	—2.0	— .2	40 26 31.52	+ 9 50.29	+1.14	— 36	+24	22.83	+3	15.9
			29.0517	14.2730	+145	+1.0	+ .6	40 42 36.61	— 6 13.75	— 4	+ 24	—12	22.94	+3	
			8.6963 ^{II}	31.9570 ^{IV}	+ 7	—1.6	—1.4	40 26 34.71	+ 9 47.70	+1.09	— 45	+19	23.24	+3	
		6	19.0333	20.4210	— 2	— .4	+1.2	40 36 56.70	— 35.06	+ 12	+ 8	— 1	21.83	+3	15.6
			27.2217	11.9657	— 35	+ .6	+1.4	40 42 47.53	— 6 25.35	— 3	+ 28	—13	22.30	+3	
			21.9173	17.7567	— 5	— .2	+ .5	40 34 37.17	+ 1 45.10	+ 10	+ 3	+ 4	23.44	+2	
			28.4523	14.1320	+110	+2.9	+1.5	40 42 24.33	— 6 2.08	— 4	+ 69	—10	22.80	+3	
			18.3837	21.9803	+ 4	+ .4	+ .4	40 37 53.28	— 1 30.88	+ 4	+ 12	— 3	22.53	+3	15.5
	VI	1	16.5360	24.7137	+ 29	+ .1	+1.3	40 32 55.60	+ 3 26.68	+ 13	+ 18	+ 6	22.65	+2	15.3
			23.8983	17.3273	+ 22	—2.0	—1.7	40 33 37.20	+ 2 46.07	+ 11	— 56	+ 5	22.87	+2	
			29.3100	12.9653	+110	—2.2	—2.4	40 43 17.08	— 6 53.23	— 5	— 68	—13	22.99	+2	
			23.6360	17.5713	+ 21	—1.1	— .2	40 33 50.06	+ 2 33.28	+ 10	— 21	+ 4	23.27	+2	
			24.2613	18.5700	+ 49	—1.1	—1.0	40 38 46.77	— 2 23.91	+ 3	— 32	— 5	22.52	+1	
		6	8.8623 ^{II}	29.9130 ^{IV}	— 4	+ .3	— .4	40 27 29.48	+ 8 51.83	+1.08	0	+19	22.58	+1	
			22.2410	19.5787	+ 13	+ .4	— .2	40 37 30.58	— 1 7.29	+ 4	+ 4	— 2	23.35	+1	
			13.3650	29.8467	+154	+1.1	+1.6	40 43 19.64	— 6 56.80	— 5	+ 40	—13	23.06	+1	14.9
			29.3440 ^{IV}	9.6343 ^{II}	— 61	—2.3	—1.6	40 28 4.21	+ 8 17.81	+1.05	— 59	+15	22.63	0	
			23.7393	17.9333	+ 29	—1.4	— .8	40 33 56.83	+ 2 26.76	+ 10	— 34	+ 4	23.39	0	15.5

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Feb. 20	VI 11	D	13.6843	26.2473	0	+.8	+.8	40 31 6.08	+ 5 17.41	+ 16	+ 24	+10	40 36 23.99	0	
Feb. 24	V 12	R	30.4503	9.0823	- 29	-.1	0	40 27 22.10	+ 8 59.79	+ 23	- 1	+18	22.29	-1	14.3
	V 1	R	26.2410	10.5270	-150	+.7	+.9	40 29 45.39	+ 6 36.58	+ 17	+ 23	+11	22.48	+3	33.2
	2		18.3220	23.1693	+ 22	-.7	-.8	40 38 25.21	- 2 2.51	+ 3	- 22	- 4	22.47	+3	32.9
	3		9.7937 ^{II}	33.1600 ^{IV}	+ 30	-.2	-2.1	40 26 31.49	+ 9 50.35	+1.13	- 30	+24	22.91	+3	
	4		13.9900	28.7470	+120	-1.3	-.3	40 42 36.56	- 6 13.09	- 4	- 26	-12	23.05	+3	
Feb. 25	IX 5	D	33.3020 ^{IV}	10.0470 ^{II}	+ 33	-.1	+.8	40 26 34.70	+ 9 47.55	+1.08	+ 9	+19	23.61	+3	32.6
	4		20.6003	18.7913	- 2	-2.0	-1.9	40 35 33.01	+ 45.70	+ 7	- 58	+ 2	23.22	-9	26.1
	5		20.1780	17.4470	- 20	-2.3	-2.7	40 37 32.43	- 1 8.94	+ 5	- 74	- 2	22.78	-8	
	6		18.5430	19.4633	- 5	-2.3	-2.6	40 36 46.38	- 23.23	+ 8	- 72	- 1	22.50	-8	
	7		32.3847 ^{IV}	8.9740 ^{II}	+ 15	-2.5	-2.2	40 46 16.70	- 9 51.47	- 93	- 71	-17	23.42	-9	
	X 1		14.2620	26.4707	+ 26	-1.3	-2.5	40 41 31.64	- 5 8.49	- 3	- 54	- 9	22.49	-9	25.9
	2		10.7317 ^{II}	31.1507 ^{IV}	0	-2.2	-2.9	40 27 46.75	+ 8 35.85	+1.05	- 75	+17	23.07	-8	
	3		16.6893	19.7503	- 32	-1.4	-2.3	40 35 6.77	+ 1 17.25	+ 8	- 53	+ 2	23.59	-9	25.0
	4		13.5427 ^{II}	29.1233 ^{IV}	- 34	-.7	-1.8	40 29 48.23	+ 6 33.65	+1.00	- 35	+11	22.64	-9	25.0
	5		31.9417 ^{IV}	11.2273 ^{II}	+ 8	-1.5	-2.7	40 45 8.11	- 8 43.33	- 86	- 60	-20	23.12	-8	
	6		22.3937	17.7497	+ 2	-1.7	-1.7	40 34 25.53	+ 1 57.33	+ 10	- 51	+ 4	22.49	-9	
	7		14.9833	26.4310	+ 47	-.9	-2.0	40 31 33.62	+ 4 49.20	+ 14	- 41	+ 8	22.63	-9	
Feb. 26	V 8	D	29.7397	10.0820	- 14	-.8	-1.7	40 44.39.94	- 8 16.58	- 8	- 35	-15	22.78	-9	
	1		12.3153	28.0330	+ 16	-.9	-.7	40 29 45.28	+ 6 37.10	+ 17	- 24	+11	22.42	+3	30.6
	3		30.2997 ^{IV}	6.9163 ^{II}	- 28	-1.6	-2.5	40 26 31.53	+ 9 50.66	+1.11	- 60	+24	22.94	+3	
	4		27.4153	12.6407	+ 2	-.3	-.1	40 42 36.61	- 6 13.25	- 4	- 6	-12	23.14	+3	
	5		7.0743 ^{II}	30.3373 ^{IV}	- 25	+.7	-.7	40 26 34.76	+ 9 47.62	+1.06	+ 3	+19	23.66	+3	30.4
	6		22.4760	21.1527	+ 17	+.8	-1.0	40 36 56.82	- 33.47	+ 12	0	- 1	23.46	+3	
	7		12.6973	27.9343	+ 28	-1.0	-.2	40 42 47.68	- 6 24.99	- 3	- 19	-13	22.34	+3	30.2
	8		21.1233	25.2770	+ 79	+1.4	0	40 34 37.37	+ 1 45.13	+ 10	+ 24	+ 4	22.88	+3	
	9		13.2937	27.5787	+ 38	-2.2	-3.5	40 42 24.59	- 6 0.84	- 4	- 82	-10	22.79	+3	
	10		23.2047	19.6333	+ 29	+.1	-.3	40 37 53.56	- 1 30.30	+ 4	- 2	- 3	23.25	+3	30.5
	VI 1		26.1853	17.9843	+102	-.8	-.3	40 32 55.91	+ 3 27.43	+ 13	- 17	+ 6	23.36	+3	
	2		18.5827	25.0970	+ 71	+1.6	+.7	40 33 37.56	+ 2 44.75	+ 11	+ 36	+ 5	22.83	+2	
	3		12.0590	28.4413	+ 24	-1.2	+.3	40 43 17.46	- 6 53.92	- 5	- 16	-13	23.20	+2	
	4		18.2120	24.2380	+ 44	-.6	-1.2	40 33 50.51	+ 2 32.35	+ 10	- 25	+ 4	22.75	+2	29.7
	5		18.5180	24.2187	+ 46	0	+.1	40 38 47.22	- 2 24.13	+ 3	+ 1	- 5	23.08	+2	
	6		32.1630 ^{IV}	11.1103 ^{II}	+ 10	-.3	-.8	40 27 29.92	+ 8 51.87	+1.05	- 15	+19	22.88	+1	
	7		19.0367	21.7020	+ 8	-1.7	-1.8	40 37 31.12	- 1 7.35	+ 4	- 52	- 2	23.27	+1	
	8		28.8280	12.3463	+ 56	-.7	-1.3	40 43 20.19	- 6 56.51	- 5	- 29	-13	23.21	+1	
	9		11.2593 ^{II}	30.9410 ^{IV}	- 3	+.8	-.4	40 28 4.78	+ 8 17.21	+1.02	+ 8	+15	23.24	+1	29.5
	10		18.5827	24.3290	+ 49	+1.8	+.5	40 33 57.44	+ 2 25.29	+ 9	+ 37	+ 4	23.23	+1	
	11		27.8710	15.3837	+120	-.9	-1.2	40 31 6.75	+ 5 15.77	+ 16	- 31	+10	22.47	0	
	12		11.4043	32.7450	+261	+.2	-.7	40 27 22.71	+ 8 59.68	+ 23	- 5	+18	22.75	0	29.1
	IX 4	R	19.3803	21.1673	+ 2	-1.5	-1.7	40 35 38.00	+ 45.15	+ 7	- 47	+ 2	22.77	-9	25.6
	5		19.6880	22.4770	+ 20	-.3	-.6	40 37 32.41	- 1 10.51	+ 5	- 12	- 2	21.81	-8	
	6		24.3017	23.3807	+ 17	+1.1	+.2	40 36 46.35	- 23.31	+ 8	+ 21	- 1	23.32	-8	
	7		9.4877 ^{II}	32.9343 ^{IV}	+ 23	+.2	+1.0	40 46 16.67	- 9 52.40	- 92	+ 16	-17	23.34	-9	25.3
	X 1		26.8453	14.6623	+ 54	-.5	-.2	40 41 31.60	- 5 7.93	- 3	- 11	- 9	23.44	-9	
	2		31.9047 ^{IV}	11.5207 ^{II}	+ 5	-.2	+1.2	40 27 46.70	+ 8 34.99	+1.04	+ 12	+17	23.02	-8	
	3		22.8323	19.8053	+ 23	-.8	0	40 35 6.71	+ 1 16.53	+ 8	- 13	+ 2	23.21	-9	
	5		10.4587 ^{II}	31.1700 ^{IV}	+ 2	-.7	-.5	40 45 8.03	- 8 43.25	- 85	- 18	-20	23.55	-8	24.6
	6		19.0450	23.7043	+ 38	-.6	-1.3	40 34 25.44	+ 1 57.81	+ 10	- 27	+ 4	23.12	-9	
	7		27.4363	15.9707	+116	-.9	-1.1	40 31 33.52	+ 4 49.95	+ 14	- 29	+ 8	23.40	-9	24.2
Mar. 1	V 8	D	10.6640	30.3123	+ 55	+.2	+.2	40 44 39.82	- 8 16.52	- 8	+ 6	-15	23.13	-9	23.9
	2		22.8913	18.0143	+ 13	+1.9	+2.2	40 38 25.28	- 2 3.23	+ 3	+ 61	- 4	22.65	+3	34.9
	3		30.1820 ^{IV}	6.8667 ^{II}	- 28	+1.1	+1.9	40 26 31.65	+ 9 43.92	+1.11	+ 43	+24	22.85	+3	
	4		29.1017	14.3083	+147	+2.3	+2.5	40 42 36.74	- 6 14.08	- 4	+ 71	-12	23.21	+3	
	5		8.1820 ^{II}	31.4187 ^{IV}	- 4	+1.1	+1.4	40 26 34.90	+ 9 46.99	+1.06	+ 37	+19	23.51	+3	

1898	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections.				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Mar. 1	V	6	20.4650	21.8460	+ 10	- 2	- .8	40 36 57.01	- 34.91	+ 12	- 14	- 1	40 36 22.07	+ 3	34.4
			27.9883	12.7530	+ 33	+ 1.3	+ .4	40 42 47.89	- 6 24.95	- 3	+ 27	- 13	23.05	+ 3	
			21.4797	17.3397	- 16	+ 2.5	+ 2.3	40 34 37.61	+ 1 44.54	+ 10	+ 72	+ 4	23.01	+ 3	
			27.6783	13.3567	+ 44	+ 2.2	+ .9	40 42 24.85	- 6 1.90	- 4	+ 49	- 10	23.30	+ 3	
			18.0240	21.6593	- 3	+ 2.6	+ 3.3	40 37 53.84	- 1 31.83	+ 4	+ 87	- 3	22.89	+ 3	
	VI	1	15.6463	23.8333	- 14	+ .4	- .2	40 32 56.21	+ 3 26.79	+ 13	+ 4	+ 6	23.23	+ 3	33.6
			24.5393	18.0423	+ 49	+ 2.2	+ 2.4	40 33 37.89	+ 2 44.25	+ 11	+ 68	+ 5	22.98	+ 3	33.8
			27.2347	10.8310	- 93	- 1.6	- 1.1	40 43 17.79	- 6 54.15	- 5	- 41	- 13	23.05	+ 2	
			22.2253	16.2377	- 27	+ 1.9	+ 2.0	40 33 50.89	+ 2 31.19	+ 10	+ 58	+ 4	22.80	+ 2	33.8
			23.3763	17.6220	+ 17	+ 1.8	+ .4	40 38 47.61	- 2 25.40	+ 3	+ 35	- 5	22.54	+ 2	
	IX	6	10.9857 ⁱⁱ	32.0203 ^{iv}	+ 9	- .6	- .4	40 27 30.29	+ 8 51.39	+ 1.05	- 15	+ 19	22.77	+ 2	
			17.6657	18.6057	- 11	- .6	- .4	40 36 46.32	- 23.72	+ 8	- 15	- 1	22.52	- 8	32.3
	X	1	32.5990 ^{iv}	9.1590 ⁱⁱ	+ 18	+ .3	- .9	40 46 16.64	- 9 52.19	- 92	- 6	- 17	23.30	- 9	32.3
			13.5987	25.8327	- 22	- 1.3	- 1.3	40 41 31.51	- 5 9.00	- 3	- 39	- 9	22.00	- 9	31.1
		2	9.5403 ⁱⁱ	29.9260 ^{iv}	0	0	+ .4	40 27 46.58	+ 8 34.99	+ 1.04	+ 5	+ 17	22.83	- 8	
			19.3247	22.3503	+ 16	0	+ .5	40 35 6.58	+ 1 16.48	+ 8	+ 6	+ 2	23.22	- 9	
		3	12.7807 ⁱⁱ	28.3507 ^{iv}	- 16	+ 1.9	+ 1.8	40 29 48.01	+ 6 33.29	+ 99	+ 55	+ 11	22.95	- 9	
			30.0800 ^{iv}	9.3513 ⁱⁱ	- 2	+ 1.2	+ 1.1	40 45 7.86	- 8 43.65	- 85	+ 34	- 20	23.50	- 8	
			22 6023	17.9747	+ 8	+ .6	+ .2	40 34 25.20	+ 1 56.92	+ 10	+ 12	+ 4	22.38	- 9	
			14.2420	25.6970	- 4	+ 1.0	- .5	40 31 33.24	+ 4 49.37	+ 14	+ 10	+ 8	22.93	- 9	29.8
			29.5557	9.8980	- 31	+ 2.0	+ 1.3	40 44 39.53	- 8 16.52	- 8	+ 51	- 15	23.29	- 9	29.6
			23.1143	21.7887	+ 19	- 3.6	- 3.5	40 36 57.06	- 33.53	+ 12	- 1.06	- 1	22.58	+ 3	32.3
			13.9377	29.1460	+ 139	- 2.8	- 1.9	40 42 47.97	- 6 24.55	- 3	- 72	- 13	22.54	+ 3	
Mar. 6	V	6	19.0060	23.1660	+ 27	+ 1.2	+ .8	40 34 37.75	+ 1 45.16	+ 9	+ 31	+ 4	23.35	+ 3	
			13.4760	27.7803	+ 54	- 2.2	- 1.3	40 42 25.04	- 6 1.49	- 4	- 54	- 10	22.87	+ 3	
			22.0450	18.4460	+ 4	+ .8	- .2	40 37 54.08	- 1 30.93	+ 4	+ 11	- 3	23.27	+ 3	
			25.8230	17.6800	+ 83	+ .2	+ .9	40 32 56.49	+ 3 25.92	+ 13	+ 15	+ 6	22.75	+ 3	32.5
			17.8220	24.3147	+ 40	+ 1.5	+ 1.6	40 33 38.23	+ 2 44.12	+ 11	+ 46	+ 5	22.97	+ 3	
	VI	1	13.0907	29.4900	+ 125	- 1.7	- 1.3	40 43 18.15	- 6 54.60	- 5	- 46	- 13	22.91	+ 3	32.6
			16.3383	22.3380	- 23	+ 1.9	+ .6	40 33 51.34	+ 2 31.50	+ 10	+ 40	+ 4	23.38	+ 2	32.4
			18.9083	24.6263	+ 61	- 2.5	- 2.2	40 38 48.09	- 2 24.60	+ 3	- 71	- 5	22.76	+ 2	32.4
			31.8817 ^{iv}	10.8793 ⁱⁱ	+ 8	+ .9	+ 1.2	40 27 30.77	+ 8 50.58	+ 1.05	+ 31	+ 19	22.90	+ 2	
			18.2547	20.9893	- 6	- .4	- .2	40 37 32.12	- 1 9.07	+ 4	- 9	- 2	22.98	+ 2	
		2	29.3043	12.7720	+ 101	+ .6	- .7	40 43 21.23	- 6 57.90	- 5	+ 1	- 13	23.16	+ 2	31.9
			9.7057 ⁱⁱ	29.8433 ^{iv}	0	- 1.0	- 2.3	40 28 5.86	+ 8 16.09	+ 1.02	- 46	+ 15	22.66	+ 1	32.2
			17.3737	23.0897	+ 8	+ .9	0	40 33 58.55	+ 2 24.41	+ 10	+ 15	+ 4	23.25	+ 1	31.6
			27.5433	15.0923	+ 98	0	0	40 31 7.82	+ 5 14.79	+ 16	0	+ 10	22.87	+ 1	
			10.2643	31.5980	+ 117	- 1.1	- 2.3	40 27 23.91	+ 8 59.23	+ 23	- 48	+ 18	23.07	0	30.9
Mar. 7	V	6	17.8960	19.3007	- 12	+ 2.3	+ 3.8	40 36 57.03	- 35.45	+ 12	+ 88	- 1	22.57	+ 3	36.5
			29.1957	13.9573	+ 142	+ 1.7	+ 1.2	40 42 47.95	- 6 25.31	- 3	+ 44	- 13	22.92	+ 3	36.4
			21.7667	17.6493	- 8	+ 4.0	+ 3.2	40 34 37.74	+ 1 43.99	+ 10	+ 1.09	+ 4	22.96	+ 3	
			27.6000	13.2557	+ 37	+ 2.7	+ 2.0	40 42 25.04	- 6 2.45	- 4	+ 72	- 10	23.17	+ 3	
			20.8227	24.4527	+ 55	+ 3.3	+ 1.5	40 37 54.08	- 1 31.84	+ 4	+ 76	- 3	23.01	+ 3	
	VI	1	15.6580	23.8153	- 13	+ 1.3	- .1	40 32 56.50	+ 3 26.03	+ 13	+ 20	+ 6	22.92	+ 3	35.8
			23.0273	16.5187	- 10	+ .1	- .6	40 33 38.25	+ 2 44.39	+ 11	- 6	+ 5	22.74	+ 3	
			27.1980	10.7780	- 98	- 1.7	- 1.7	40 43 18.17	- 6 54.55	- 5	- 51	- 13	22.93	+ 3	35.9
			23.5397	17.5623	+ 19	- .1	- 1.1	40 33 51.38	+ 2 31.05	+ 10	- 15	+ 4	22.42	+ 2	
			22.8730	17.1453	0	- 2.0	- .9	40 38 48.13	- 2 24.69	+ 3	- 45	- 5	22.97	+ 2	
		2	9.6383 ⁱⁱ	30.6507 ^{iv}	+ 1	+ .1	0	40 27 30.81	+ 8 50.81	+ 1.05	+ 1	+ 19	22.87	+ 2	
			22.4750	19.7257	+ 20	+ .1	- .4	40 37 32.18	- 1 9.50	+ 4	- 3	- 2	22.67	+ 2	
			11.5623	28.1050	- 18	- .5	- .4	40 43 21.30	- 6 57.85	- 5	- 13	- 13	23.14	+ 2	35.0
			30.8263 ^{iv}	11.2267 ⁱⁱ	+ 1	+ 2.3	+ 1.8	40 28 5.94	+ 8 15.11	+ 1.02	+ 62	+ 15	22.84	+ 1	34.6
			21.5293	15.7893	- 45	- .9	- 1.3	40 33 58.69	+ 2 24.89	+ 10	- 32	+ 4	23.40	+ 1	
		3	12.9670	25.4763	- 57	- 1.5	- 1.8	40 31 7.91	+ 5 15.86	+ 16	- 48	+ 10	23.55	+ 1	
			30.4597	9.1467	- 24	+ .4	+ .5	40 27 24.01	+ 8 58.34	+ 23	+ 13	+ 18	22.89	+ 1	34.3

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Mar. 7	IX 7 R		9.5637 ^{II}	33.0257 ^{IV}	+ 25	— .2	— .4	40 46 17.09	— 9.52.78	— 92	— 8	— 17	40 36 23.14	— 8	28.4
	X 1		26.0383	13.8227	— 5	— .7	— 1.1	40 41 31.87	— 5 8.59	— 3	— 26	— 9	22.90	— 9	
Mar. 13	2		31.8617 ^{IV}	11.4630 ^{II}	+ 4	— 1.4	— 1.0	40 27 46.86	+ 8 35.34	+ 1.04	— 37	+ 17	23.04	— 9	28.2
	3		22.0240	19.0077	+ 9	— 1.7	— .7	40 35 6.83	+ 1 16.22	+ 8	— 38	+ 2	22.77	— 9	
	V 8 R		19.3360	23.5513	+ 36	— 3.8	— 4.7	40 34 37.84	+ 1 46.57	+ 10	— 1.25	+ 4	23.30	+ 3	41.7
	10		22.0520	18.4920	+ 6	— 1.1	— 1.7	40 37 54.26	— 1 29.94	+ 4	— 41	— 3	23.92	+ 3	
	VI 1		25.7337	17.5520	+ 78	— 1.8	— 3.0	40 32 56.72	+ 3 26.87	+ 13	— 69	+ 6	23.09	+ 3	
	2		18.3197	24.8280	+ 60	+ .6	+ 1.1	40 33 38.53	+ 2 44.56	+ 11	+ 24	+ 5	23.49	+ 3	
	3		14.2413	30.6213	+ 234	— 2.4	— 1.9	40 43 18.47	— 6 54.35	— 5	— 65	— 13	23.29	+ 3	39.9
	4		17.6960	23.6983	+ 24	— .6	— .9	40 33 51.77	+ 2 31.69	+ 10	— 21	+ 4	23.39	+ 3	
	5		17.9867	23.7047	+ 29	— 1.9	— 2.4	40 38 48.54	— 2 24.52	+ 3	— 63	— 5	23.37	+ 3	
	6		32.2890 ^{IV}	11.2560 ^{II}	+ 11	— 1.6	— 1.9	40 27 31.22	+ 8 51.34	+ 1.05	— 52	+ 19	23.28	+ 2	
	7		19.3573	22.0983	+ 13	— 2.2	— 2.6	40 37 32.69	— 1 9.27	+ 4	— 71	— 2	22.73	+ 2	39.2
	8		28.7650	12.2357	+ 49	— 3.4	— 3.4	40 43 21.84	— 6 57.66	— 5	— 1.02	— 13	22.98	+ 2	39.4
	9		11.6193 ^{II}	31.2543 ^{IV}	— 2	— 1.2	— 2.1	40 28 6.51	+ 8 15.99	+ 1.02	— 47	+ 15	23.20	+ 2	
	10		17.2973	22.9643	+ 4	— 1.0	— .7	40 33 59.33	+ 2 23.17	+ 10	— 26	+ 4	22.38	+ 2	38.6
	11		27.8617	15.4393	+ 120	— 1.6	— 1.3	40 31 8.53	+ 5 14.10	+ 16	— 44	+ 10	22.45	+ 1	38.4
	12		9.9917	31.3180	+ 84	— 1.9	— 2.6	40 27 24.67	+ 8 58.93	+ 23	— 66	+ 18	23.35	+ 1	
	IX 7 D		31.2107 ^{IV}	7.7600 ^{II}	— 11	— .9	— 1.3	40 46 17.47	— 9 52.38	— 92	— 31	— 17	23.69	— 8	34.6
	X 1		13.0340	25.2713	— 62	— .6	— .9	40 41 32.17	— 5 8.97	— 3	— 21	— 9	22.87	— 8	33.9
	2		8.8367 ^{II}	29.2903 ^{IV}	— 0	— 2.0	— 3.0	40 27 47.09	+ 8 36.69	+ 1.04	— 73	+ 17	24.26	— 8	34.0
	3		19.6233	22.6280	+ 19	+ .5	— .2	40 35 7.05	+ 1 15.96	+ 8	+ 6	+ 2	23.17	— 9	
	4		12.4800 ^{II}	28.0383 ^{IV}	— 7	+ 1.0	+ .1	40 29 48.42	+ 6 33.01	+ 99	+ 18	+ 11	22.71	— 9	
	5		28.9247 ^{IV}	8.2390 ^{II}	— 6	— 2.0	— 3.1	40 45 8.10	— 8 42.56	— 85	— 74	— 20	23.75	— 8	34.1
Mar. 16	VI 1 D		14.8447	23.0047	— 52	+ 1.2	+ .6	40 32 56.92	+ 3 26.02	+ 13	+ 28	+ 6	23.41	+ 3	28.0
	2		23.9423	17.4557	+ 26	0	+ .5	40 33 38.75	+ 2 43.94	+ 11	+ 6	+ 5	22.91	+ 3	
	3		29.1750	12.7430	+ 93	— .6	+ .1	40 43 18.71	— 6 55.35	— 5	— 8	— 13	23.10	+ 3	28.3
	4		21.9350	15.9703	— 36	+ 2.2	+ 1.9	40 33 52.07	+ 2 30.60	+ 10	— 62	+ 4	23.43	+ 3	
	6		10.0920 ^{II}	31.0797 ^{IV}	+ 4	+ .9	+ .5	40 27 31.53	+ 8 50.22	+ 1.05	+ 22	+ 19	23.21	+ 2	27.7
	9		30.3523 ^{IV}	10.7953 ^{II}	0	+ 2.5	+ 3.9	40 28 6.92	+ 8 14.06	+ 1.02	+ 93	+ 15	23.08	+ 2	27.7
Mar. 17	10		22.2570	16.6390	— 19	+ 2.7	+ 3.4	40 33 59.76	+ 2 21.88	+ 10	+ 90	+ 4	22.68	+ 2	27.6
	X 2 R		30.7600 ^{IV}	10.3993 ^{II}	0	+ .9	+ 1.2	40 27 47.38	+ 8 34.38	+ 1.04	+ 31	+ 17	23.28	— 8	27.0
	3		21.9487	18.9827	+ 8	+ 1.8	+ 2.3	40 35 7.34	+ 1 14.95	+ 8	+ 60	+ 2	22.99	— 8	
	4		26.5750 ^{IV}	10.9973 ^{II}	+ 32	— 2.2	— 1.9	40 29 48.69	+ 6 33.62	+ 99	— 62	+ 11	22.79	— 9	
	5		10.8650 ^{II}	31.6220 ^{IV}	+ 5	0	+ 1.6	40 45 8.28	— 8 44.40	— 85	+ 20	— 20	23.03	— 7	
	6		18.8243	23.4907	+ 33	+ .9	0	40 34 25.43	+ 1 57.98	+ 10	+ 15	+ 4	23.70	— 8	27.0
	7		26.6383	15.1783	+ 61	+ .4	+ .4	40 31 33.31	+ 4 49.67	+ 14	+ 12	+ 8	23.32	— 9	
	8		10.0507	29.6780	— 15	0	+ .8	40 44 39.44	— 8 15.80	— 8	+ 10	— 15	23.51	— 9	
	9		12.8397	30.2703	+ 156	+ 1.4	+ 1.5	40 43 43.41	— 7 20.75	— 5	+ 43	— 13	22.91	— 9	
	10		32.5117 ^{IV}	8.4960 ^{II}	+ 12	+ .3	0	40 46 31.13	— 10 6.74	— 92	+ 5	— 17	23.35	— 9	26.4
Mar. 18	XI 1		29.8580	14.2937	+ 189	— .3	— .2	40 42 57.09	— 6 33.67	— 1	— 7	— 14	23.20	— 8	26.4
	VI 1 D		14.9480	23.0873	— 47	+ .8	+ 2.0	40 32 56.97	+ 3 25.50	+ 13	+ 39	+ 6	23.05	+ 3	35.5
	2		23.1453	16.6783	— 3	+ 2.4	+ 1.4	40 33 38.83	+ 2 43.87	+ 11	+ 59	+ 5	22.95	+ 3	
	3		12.4300	28.8700	+ 63	— .5	+ .8	40 43 18.80	— 6 55.47	— 5	+ 2	— 13	23.17	+ 3	
	4		16.9543	22.9070	— 3	+ .7	+ .8	40 33 52.20	+ 2 30.37	+ 10	+ 22	+ 4	22.93	+ 3	34.4
	5		17.5140	23.3120	+ 13	+ .9	+ .9	40 38 49.00	— 2 26.50	+ 3	+ 27	— 5	22.75	+ 3	
	6		29.0133 ^{IV}	8.0480 ^{II}	— 9	+ .3	+ .4	40 27 31.68	+ 8 49.60	+ 1.05	+ 10	+ 19	22.62	+ 2	
	7		18.5097	21.2970	— 2	+ .1	+ 1.8	40 37 33.24	— 1 10.41	+ 4	+ 24	— 2	23.09	+ 3	
	8		30.0120	13.4353	+ 169	+ .4	+ 1.2	40 43 22.43	— 6 59.19	— 5	+ 22	— 13	23.28	+ 2	32.5
	9		11.1673 ^{II}	30.7207 ^{IV}	0	+ 1.6	+ 3.0	40 28 7.14	+ 8 13.96	+ 1.02	+ 66	+ 15	22.93	+ 2	
	10		17.1277	22.7583	— 2	+ 2.3	+ 2.6	40 34 0.01	+ 2 22.23	+ 10	+ 72	+ 4	23.10	+ 2	32.0
	11		26.5400	14.1423	+ 24	0	+ .4	40 31 9.22	+ 5 13.25	+ 16	+ 5	+ 10	22.78	+ 2	31.9
	12		10.1683	31.4440	+ 101	— 2.0	— 2.4	40 27 25.41	+ 8 57.72	+ 23	— 65	+ 18	22.89	+ 1	
	VII 2		32.3903	17.9533	+ 442	+ 1.3	+ 1.9	40 30 16.48	+ 6 5.82	+ 18	+ 46	+ 12	23.06	+ 1	
			16.7180	25.6680	+ 64	+ .4	+ 1.6	40 40 9.01	— 3 46.26	0	+ 27	— 7	22.95	+ 1	

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Mar. 18	VII 3		22.1717	19.1243	+ 12	+ .8	+ .9	40 35 5.53	+ 1 17.02	+ 8	+ 25	+ 2	22.90	+1	30.6
			29.6657	12.2910	+100	+1.4	+2.6	40 29 2.63	+ 7 19.17	+ 23	+ 57	+13	22.73	0	
			28.7360	14.4277	+134	+1.5	+ .9	40 42 24.05	- 6 1.79	- 9	+ 37	-10	22.44	0	
			25.8000	13.9420	- 9	+2.3	+2.1	40 41 21.64	- 4 59.54	- 6	+ 66	- 8	22.62	0	29.2
			19.4183	21.7807	+ 8	- .1	0	40 37 22.56	- 59.70	+ 3	- 1	- 2	22.86	-1	28.9
			26.8167	14.3087	+ 41	+1.6	+2.0	40 31 5.62	+ 5 16.08	+ 22	+ 53	+12	22.57	-1	
			19.1637	20.0373	- 3	+1.7	+2.3	40 36 44.45	- 22.06	+ 5	+ 58	- 1	23.01	-1	28.9
			10.2887 ⁱⁱ	30.6587 ^{iv}	0	- .2	+1.3	40 27 47.50	+ 8 34.62	+1.10	+ 13	+17	23.52	-8	26.3
	X 2	D	18.4167	21.4193	- 2	+ .4	+ .1	40 35 7.47	+ 1 15.85	+ 9	+ 8	+ 2	23.51	-8	
			12.5433 ⁱⁱ	28.0977 ^{iv}	- 9	+ .6	+ .4	40 29 48.81	+ 6 32.94	+1.04	+ 15	+11	23.05	-9	
			30.8693 ^{iv}	10.1347 ⁱⁱ	+ 1	0	0	40 45 8.37	- 8 43.83	- 92	0	-20	23.42	-7	
			21.3637	16.7063	- 27	- .8	- .8	40 34 25.52	+ 1 57.60	+ 12	- 24	+ 4	23.04	-8	25.9
			18.6780	30.0937	+296	+1.2	+ .5	40 31 33.39	+ 4 49.14	+ 18	+ 27	+ 8	23.06	-9	25.6
			28.7780	11.3620	+ 7	+ .2	+ .2	40 43 43.46	- 7 20.00	- 11	+ 6	-13	23.28	-9	
			7.4307 ⁱⁱ	31.4150 ^{iv}	- 15	-4.1	-4.0	40 46 31.17	-10 5.89	-1.00	-1.21	-17	22.90	-9	24.4
			13.3967	28.9520	+107	- .7	-1.1	40 42 57.11	- 6 33.25	- 6	- 26	-14	23.40	-8	24.5
	VI 1	D	12.7623	20.9617	-153	-1.0	-1.7	40 32 56.93	+ 3 26.73	+ 16	- 39	+ 6	23.49	+3	44.4a
			23.5910	17.0833	+ 13	- .8	- .5	40 33 38.83	+ 2 44.42	+ 13	- 20	+ 5	23.23	+3	
			27.0720	10.6097	-113	0	+ .8	40 43 18.80	- 6 55.55	- 10	+ 10	-13	23.12	+3	44.0
			23.0603	17.0923	+ 2	- .2	- .9	40 33 52.27	+ 2 30.75	+ 12	- 15	+ 4	23.03	+3	44.0
Mar. 27	VI 2	D	21.9853	16.2020	- 31	+ .7	+ .3	40 38 49.08	- 2 26.01	+ 1	+ 16	- 5	23.19	+3	43.4
			24.4967	17.9857	+ 49	- .9	-1.0	40 33 38.91	+ 2 44.60	+ 13	- 27	+ 4	23.41	+3	
			21.4170	15.4333	- 57	-1.3	-2.0	40 33 52.47	+ 2 31.01	+ 12	- 46	+ 4	23.18	+3	40.2
			23.3303	17.5667	+ 15	-1.9	-2.7	40 38 49.32	- 2 25.63	+ 1	- 64	- 5	23.01	+3	
			9.7427 ⁱⁱ	30.7300 ^{iv}	- 3	-1.6	-1.7	40 27 32.01	+ 8 50.16	+1.12	- 47	+19	23.01	+3	
			21.7447	18.9753	+ 6	-1.6	-2.4	40 37 33.72	- 1 9.97	+ 3	- 56	- 2	23.20	+3	
			11.2663	27.8787	- 42	-1.0	-2.2	40 43 22.96	- 6 59.54	- 10	- 44	-13	22.75	+3	38.6
			29.4730 ^{iv}	9.9280 ⁱⁱ	- 00	- .5	-1.1	40 28 7.75	+ 8 13.73	+1.09	- 22	+15	22.50	+3	
			23.3143	17.6467	+ 15	-3.2	-3.1	40 34 0.73	+ 2 23.21	+ 12	- 90	+ 4	23.20	+2	38.1
			13.9233	26.3200	+ 7	- .8	-1.0	40 31 9.94	+ 5 13.17	+ 20	- 25	+10	23.16	+2	38.2
	VII 1		30.6153	9.4080	0	+ .1	+1.0	40 27 26.21	+ 8 55.72	+ 30	+ 14	+17	22.54	+2	
			11.5383	26.0230	-105	- .6	- .8	40 30 17.29	+ 6 5.63	+ 23	- 20	+12	23.07	+2	
			24.0440	15.0730	- 24	- .1	+ .1	40 40 9.69	- 3 46.55	- 3	0	- 7	23.04	+2	37.9
			19.2937	22.3127	+ 14	+1.3	+1.5	40 35 6.53	+ 1 16.29	+ 9	+ 40	+ 2	23.33	+2	37.5
			15.0590	24.0423	- 24	+ .3	- .2	40 40 9.94	- 3 46.86	+ 2	+ 2	- 8	23.04	+1	
			12.7343	30.1117	+145	-1.0	-1.6	40 29 3.79	+ 7 19.33	+ 23	- 36	+13	23.12	+1	
			13.3923	27.7440	+ 49	+1.2	+1.9	40 42 25.27	- 6 2.66	- 9	+ 43	-10	22.85	+1	
			13.0550	24.9710	- 70	+1.7	+2.1	40 41 22.94	- 5 0.84	- 7	+ 54	- 8	22.49	+1	36.7
			22.1000	19.6830	+ 12	+ .3	0	40 37 23.90	- 1 1.08	+ 2	+ 5	- 2	22.87	0	
			11.6907	24.2183	-151	- .4	- .3	40 31 6.81	+ 5 16.08	+ 22	- 10	+12	23.13	0	36.2
	X 6	R	22.8017	21.8937	+ 15	+ .7	+ .5	40 36 45.81	- 22.97	+ 5	+ 18	- 1	23.06	0	35.6
			18.1933	22.8093	+ 14	0	+ .1	40 34 26.28	+ 1 56.64	+ 12	+ 2	+ 4	23.10	-8	32.2
			26.6067	15.1850	+ 61	- .2	- .3	40 31 34.11	+ 4 48.69	+ 18	- 7	+ 9	23.00	-9	31.7
			11.4257	31.0917	+145	+ .2	+1.3	40 44 40.16	- 8 17.17	- 15	+ 20	-15	22.89	-8	
Mar. 28			11.8483	29.3157	+ 59	+ .9	+1.5	40 43 44.04	- 7 21.42	- 11	+ 34	-13	22.72	-9	
			33.1717 ^{iv}	9.1343 ⁱⁱ	+ 28	+1.6	+1.3	40 46 31.66	-10 7.31	-1.00	+ 42	-18	23.59	-9	31.5
			29.7083	14.1197	+173	- .6	-1.3	40 42 57.43	- 6 34.24	- 6	- 26	-14	22.73	-8	30.8b
			10.6447 ⁱⁱ	34.7193 ^{iv}	+ 64	+2.8	+2.5	40 46 31.86	-10 8.34	- 95	+ 76	-23	22.60	-8	30.6
	VI 2	R	17.2440	23.7123	+ 17	+1.5	+1.4	40 33 38.96	+ 2 43.45	+ 13	+ 42	+ 4	23.00	+3	34.4a
			12.4360	28.8963	+ 65	+ .7	+ .9	40 43 18.97	- 6 55.99	- 10	+ 22	-13	22.97	+3	a
			17.6047	23.5400	+ 20	+ .6	+ .8	40 33 52.54	+ 2 29.98	+ 12	+ 20	+ 4	22.88	+3	33.6
			17.5010	23.3093	+ 13	+1.1	+ .9	49 38 49.39	- 2 26.76	+ 1	+ 29	- 5	22.88	+3	
			30.5127 ^{iv}	9.5893 ⁱⁱ	0	+3.0	+3.6	40 27 32.09	+ 8 48.57	+1.12	+ 93	+19	22.90	+3	
			18.3843	21.2270	- 4	+3.0	+3.1	40 37 33.80	- 1 11.81	+ 3	+ 86	- 2	22.86	+3	
			28.7493	12.1027	+ 41	+2.3	+2.6	40 43 23.06	- 7 0.63	- 11	+ 70	-13	22.89	+3	32.2
			17.6047	23.5400	+ 20	+ .6	+ .8	40 33 52.54	+ 2 29.98	+ 12	+ 20	+ 4	22.88	+3	33.6
			17.5010	23.3093	+ 13	+1.1	+ .9	49 38 49.39	- 2 26.76	+ 1	+ 29	- 5	22.88	+3	
			30.5127 ^{iv}	9.5893 ⁱⁱ	0	+3.0	+3.6	40 27 32.09	+ 8 48.57	+1.12	+ 93	+19	22.90	+3	
			18.3843	21.2270	- 4	+3.0	+3.1	40 37 33.80	- 1 11.81	+ 3	+ 86	- 2	22.86	+3	

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections.				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Mar. 28	VI 9		10.9057 ^{II}	30.4727 ^{IV}	0	-2.1	-4.2	40 28 7.86	+ 8 14.31	+1.09	- 86	+15	22.55	+3	
			26.9287	14.5750	+ 55	- .4	+ .8	40 31 10.07	+ 5 12.22	+ 20	+ 4	+10	22.63	+2	31.7
			10.4860	31.6947	+136	- .2	- .2	40 27 26.35	+ 8 56.12	+ 30	- 6	+17	22.88	+2	31.0
	VII 1		29.1533	14.7393	+165	+1.4	+2.0	40 30 17.42	+ 6 4.54	+ 23	+ 48	+12	22.79	+2	31.6
			15.4440	24.4530	- 3	+1.2	+1.8	40 40 9.84	- 3 47.58	- 3	+ 42	- 7	22.58	+2	
	3		22.0983	19.1050	+ 10	+1.8	+1.7	40 35 6.68	+ 1 15.65	+ 9	+ 50	+ 2	22.94	+2	
			26.5877	17.5987	+111	+1.7	+1.9	40 40 10.08	- 3 47.36	+ 2	+ 51	- 8	22.17	+1	31.6
			28.4000	11.0507	- 28	+ .3	+1.5	40 29 3.96	+ 7 18.21	+ 23	+ 24	+13	22.77	+1	
	6		27.9433	13.5910	+ 66	+1.7	+2.1	40 42 25.45	- 6 2.73	- 9	+ 54	-10	23.07	+1	
			26.0813	14.2127	+ 9	-1.4	-1.2	40 41 23.11	- 4 59.85	- 6	- 38	- 8	22.74	+1	
	8		19.4710	21.9060	+ 9	+1.7	+2.3	40 37 24.09	- 1 1.54	+ 2	+ 56	- 2	23.11	0	29.6
			27.5290	15.0490	+ 95	-1.2	- .6	40 31 6.98	+ 5 15.51	+ 22	- 26	+12	22.57	0	
			19.6797	20.5950	0	-1.4	-1.4	40 36 45.99	- 23.12	+ 5	- 40	- 1	22.51	0	29.9
	X 6 D		21.2377	16.6340	- 31	+ .7	+ .8	40 34 26.35	+ 1 56.23	+ 12	+ 21	+ 4	22.95	-8	25.4
			14.6687	26.0840	+ 27	+1.0	+ .7	40 31 34.20	+ 4 48.46	+ 18	+ 25	+ 9	23.18	-9	
	8		29.2343	9.5520	- 71	- .7	+ .1	40 44 40.23	- 8 17.06	- 15	- 10	-15	22.77	-8	
			27.9220	10.4637	- 85	+1.4	+1.1	40 43 44.09	- 7 20.84	- 11	+ 36	-13	22.37	-9	
			7.7790 ^{II}	31.8500 ^{IV}	- 4	+ .1	+ .5	40 46 31.69	-10 8.11	-1.00	+ 8	-18	22.48	-9	24.8
	XI 1		10.8140	26.4750	-126	+2.8	+2.4	40 42 57.45	- 6 35.33	- 6	+ 74	-10	22.70	-8	24.5
			30.4447 ^{IV}	6.4053 ^{II}	- 38	+1.5	- .4	40 46 31.38	-10 7.22	- 95	+ 19	-11	23.29	-8	
Mar. 29	VI 2 D		32.5147 ^{IV}	6.8353 ^{II}	- 12	-3.0	-3.2	40 25 33.34	+10 48.72	+1.12	- 88	+18	22.48	-9	24.4a
			23.6147	17.1027	+ 13	-1.0	- .3	40 33 39.00	+ 2 44.53	+ 13	- 20	+ 4	23.50	+3	38.9a
			11.6307	11.8753	+ 9	- .6	-1.6	40 43 19.02	- 6 55.07	- 10	- 30	-13	23.42	+3	a
	4		23.6710	17.6970	+ 24	-2.0	-2.8	40 33 52.61	+ 2 30.97	+ 12	- 68	+ 4	23.06	+3	37.9
			21.3797	15.5850	- 52	+ .5	- .1	40 38 49.46	- 2 26.25	+ 1	+ 6	- 5	23.23	+3	37.5
	6		8.6937 ^{II}	29.6623 ^{IV}	- 4	-1.0	-1.2	40 27 32.17	+ 8 49.69	+1.12	- 31	+19	22.86	+3	37.1
			21.3360	18.5330	- 2	-1.0	- .3	40 37 33.89	- 1 10.80	+ 3	- 20	- 2	22.90	+3	36.7
			28.3053	28.2380	- 7	-2.7	-2.7	40 43 23.16	- 6 59.51	- 10	- 77	-13	22.65	+3	36.2
	8		29.7680 ^{IV}	10.2157 ^{II}	0	+ .1	- .3	40 27 7.97	+ 8 13.92	+1.09	- 2	+15	23.11	+3	36.1
			21.5077	15.8360	- 44	-3.0	-3.6	40 34 0.97	+ 2 23.15	+ 12	- 93	+ 4	23.35	+3	35.6
	11		13.5190	25.9303	- 22	-1.7	-3.5	40 31 10.19	+ 5 13.47	+ 20	- 71	+10	23.25	+2	
			30.5833	9.3620	- 4	- .7	-1.5	40 27 26.49	+ 8 56.07	+ 30	- 30	+17	22.73	+2	34.4
			13.6290	28.0943	+ 73	- .7	-1.3	40 30 17.57	+ 6 5.59	+ 23	- 28	+12	23.23	+2	
	2		24.4860	15.5193	+ 1	-1.1	-2.6	40 40 10.48	- 3 46.52	- 3	- 50	- 7	23.36	+2	
			18.1113	21.1547	- 7	-1.5	-1.4	40 35 6.85	+ 1 16.87	+ 9	- 42	+ 2	23.41	+2	
	4		14.8383	23.8090	- 36	-2.9	-3.4	40 40 10.22	- 3 46.53	+ 2	- 89	- 8	22.74	+1	33.9
			11.0563	28.4340	- 25	+ .1	- .7	40 29 4.14	+ 7 18.92	+ 23	- 8	+13	23.34	+1	
			12.3207	26.6853	- 42	+ .2	+ .2	40 42 25.64	- 6 2.76	- 9	+ 6	-10	22.75	+1	
	7		14.2857	26.1757	+ 16	+ .7	+ .4	40 41 23.31	- 5 0.40	- 7	+ 16	- 8	22.92	+1	32.7
			21.6757	19.2763	+ 7	-1.7	-2.3	40 37 24.29	- 1 0.63	+ 2	- 56	- 2	23.10	+1	
	9		13.1687	25.6993	- 42	-1.9	-2.2	40 31 7.16	+ 5 16.43	+ 22	- 58	+12	23.35	0	32.0
			20.9560	20.0527	+ 3	-2.2	-2.8	40 36 46.21	- 22.82	+ 5	- 70	- 1	22.73	0	32.0
			18.9717	23.6403	+ 36	-4.8	-5.1	40 34 26.45	+ 1 58.03	+ 12	-1.41	+ 4	23.23	-8	28.4
	X 6 R		25.0830	13.6510	- 42	- .3	- .5	40 31 33.46	+ 4 48.69	+ 18	- 12	+ 9	22.30	-8	28.4
			11.7090	29.1400	+ 42	- .8	0	40 43 44.17	- 7 20.46	- 11	- 12	-13	23.35	-8	
	10		32.4283 ^{IV}	8.3993 ^{II}	+ 10	- .5	- .8	40 46 31.75	-10 7.06	-1.00	- 18	-18	23.33	-9	28.0
			29.6497	14.0797	+171	- .4	+ .3	40 42 57.49	- 6 33.78	- 6	- 1	-14	23.50	-8	
			9.8973 ^{II}	33.9103 ^{IV}	+ 47	-1.0	-1.0	40 46 31.39	-10 6.76	- 95	- 28	-23	23.17	-8	28.0
Apr. 2	3		6.8993 ^{II}	32.5763 ^{IV}	- 8	-1.3	-1.8	40 26 33.35	+10 48.65	+1.14	- 43	+18	22.89	-9	27.9
			31.9250 ^{IV}	10.9870 ^{II}	+ 8	+1.2	+1.6	40 27 32.33	+ 8 48.91	+1.12	+ 39	+19	22.94	+3	49.8
	7		19.1510	21.9447	+ 9	- .9	-1.4	40 37 34.12	- 1 10.59	+ 3	- 32	- 2	23.22	+3	48.3
			28.7077	12.0790	+ 38	+1.2	+ .4	40 43 23.43	- 7 0.13	- 11	+ 24	-13	23.30	+3	46.7
			10.6883 ^{II}	30.1990 ^{IV}	0	0	- .2	40 28 8.29	+ 8 12.83	+1.09	- 2	+15	22.34	+3	45.8
	10		17.7333	23.2953	+ 16	+3.7	+3.8	40 34 1.35	+ 2 20.53	+ 12	+1.07	+ 4	23.11	+3	45.0
			26.6340	14.3080	+ 32	+ .4	+1.4	40 30 10.58	+ 5 11.43	+ 20	+ 24	+10	22.55	+3	44.9

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$		Corrections				Latitude		Δ	Ther.
						A	B			Micrometer	δ	l	r				
Apr. 2	VI 12	R	10.3947	31.5660	+123	+1.1	+1.6	40 27 26.92	+ 8 55.09	+ 30	+ 38	+17		40 36 22.86	+2	43.9	
	VII 1		28.9157	14.4910	+145	— .8	— .8	40 30 18.02	+ 6 4.73	+ 23	— 9	+12		23.01	+2		
	2		26.6147	25.6417	+ 59	+ .3	+1.2	40 40 10.53	+ 3 48.17	— 4	+ 28	— 7		22.53	+2		
	3		21.8100	18.8107	+ 6	—1.5	— .8	40 35 7.41	+ 1 15.78	+ 9	— 34	+ 2		22.96	+2	43.7	
	4		25.7553	16.7373	+ 66	+1.4	+1.3	40 40 10.75	+ 3 47.96	+ 2	+ 39	— 8		23.12	+2		
	5		29.0607	11.7183	+ 38	— .8	— .5	40 29 4.79	+ 7 18.16	+ 23	— 19	+13		23.12	+2		
	6		27.2020	12.7930	0	+1.6	+2.5	40 42 26.33	+ 6 3.97	— 9	+ 57	—10		22.74	+2	42.6	
	7		25.7743	13.8213	— 15	+1.9	+1.5	40 41 24.05	+ 5 1.89	— 7	+ 49	— 8		22.50	+1	42.4	
	8		20.9037	23.3543	+ 32	— .6	+ .5	40 37 25.06	+ 1 1.98	+ 2	— 3	— 2		23.05	+1		
	9		26.9260	14.4497	+ 49	— .2	— .6	40 31 7.89	+ 5 15.27	+ 22	— 10	+12		23.40	+1		
Apr. 4	VI 10	D	20.3080	21.2257	+ 3	—2.4	—2.1	40 36 47.01	+ 23.19	+ 5	— 64	— 1		23.22	0	41.0	
	11		22.5890	16.9793	— 6	+ .3	+ .4	40 34 1.44	+ 2 21.66	+ 12	+ 10	+ 4		23.36	+3	65.0	
	12		13.1933	25.5533	— 45	+2.3	+ 2	40 31 10.68	+ 5 12.14	+ 20	+ 39	+10		23.51	+3	64.2	
	VII 3		30.9990	9.8063	+ 50	— .8	—1.4	40 27 27.06	+ 8 55.38	+ 30	— 30	+17		23.61	+2	64.2	
			16.9900	19.9953	— 27	+1.0	+ .2	40 35 7.60	+ 1 15.83	+ 9	+ 18	+ 2		23.72	+2	62.5	
	4		13.2367	22.2720	—119	—1.0	— .5	40 40 10.91	+ 3 47.90	+ 2	— 22	— 8		22.73	+2		
	5		9.9990	27.3330	—135	+ .3	+ .1	40 29 5.01	+ 7 17.45	+ 23	+ 6	+13		22.88	+2	61.6	
	X 7	D	12.8403	24.2350	— 98	—1.2	—2.2	40 31 35.27	+ 4 47.58	+ 18	— 46	+ 9		22.66	—8	47.6	
	8		28.3890	8.6793	—169	—1.9	—2.6	40 44 41.22	+ 8 17.43	— 15	— 63	—15		22.86	—8	47.3	
	9		28.6300	11 1850	— 10	—1.8	—2.7	40 43 45.01	+ 7 20.63	— 11	— 62	—13		23.52	—8		
Apr. 16	XI 10		7.0413 ⁱⁱ	31.1433 ^{iv}	— 23	+1.4	+1.0	40 46 32.52	+10 8.75	—1.00	+ 35	—18		22.94	—9	46.2	
	1		13.4543	29.1017	+117	+1.2	+1.0	40 42 58.13	+ 6 35.54	— 6	+ 32	—14		22.71	—8		
	2		31.6647 ^{iv}	7.5887 ⁱⁱ	— 9	0	+ .2	40 46 31.91	+10 8.13	— 95	+ 2	—23		22.62	—8		
	3		31.6863 ^{iv}	6.0790 ⁱⁱ	— 36	+ .4	+1.2	40 25 33.87	+10 46.75	+1.14	+ 22	+18		22.16	—9	45.1	
	4		31.8627 ^{iv}	6.4097 ⁱⁱ	— 28	— .3	0	40 25 38.94	+10 42.87	+1.14	— 5	+19		23.09	—9		
	VII 5	D	33.8527 ^{iv}	0.5550 ⁱⁱ	—220	—1.7	— .8	40 22 20.84	+14 0 54	+1.23	— 37	+26		22.50	—9	40.6	
	11		11.6150	26.0217	—103	+ .6	— .2	40 30 19.10	+ 6 3.64	+ 28	+ 7	+12		23.21	+3	48.6	
	2		23.8663	14.8340	— 36	—1.8	—1.1	40 40 11.95	+ 3 48.05	— 7	— 42	— 7		23.34	+3		
	3		17.9687	20.9293	— 9	— .8	— .6	40 35 8.82	+ 1 14.76	+ 10	— 20	+ 2		23.50	+3	48.4	
	4		14.3690	23.4060	— 58	—2.4	—3.2	40 40 12.06	+ 3 48.12	— 2	— 78	— 8		23.06	+3		
Apr. 17	5		11.0513	28.3307	— 30	+ .3	0	40 29 6.50	+ 7 16.39	+ 29	+ 5	+13		23.36	+3		
	6		13.2153	27.6683	+ 38	—1.0	—2.1	40 42 28.19	+ 6 5.16	— 14	— 42	—10		22.37	+3	48.2	
	7		13.8350	25.8057	— 14	—1.8	—1.0	40 41 26.11	+ 5 2.33	— 11	— 41	— 8		23.18	+3		
	8		20.8513	18.8187	— 6	0	— .9	40 37 27.22	+ 1 3.96	+ 2	— 12	— 2		23.14	+2	48.1	
	9		13.0357	25.4433	— 55	+ .7	0	40 31 9.88	+ 5 13.26	+ 26	+ 11	+12		23.63	+2	48.3	
	X 10		19.5830	18.5403	— 5	0	—1.2	40 36 49.31	+ 26.33	+ 5	— 15	— 1		22.87	+2		
	2		25.5227	13.2937	— 43	+ .5	+ .8	40 31 13.40	+ 5 8.78	+ 27	+ 18	+11		22.74	+1	47.8	
	7	R	24.6957	13.4067	— 63	+ .6	+ .3	40 31 37.55	+ 4 45.00	+ 22	+ 14	+ 9		23.00	—7	43.0	
	8		9.5677	29.3697	— 63	+1.0	+ .4	40 44 43.38	+ 8 20.04	— 21	+ 21	—15		23.19	—7		
	9		11.4977	29.0417	+ 27	—2.8	— .5	40 43 47.06	+ 7 23.23	— 17	— 51	—13		23.02	—7	43.1	
Apr. 18	XI 10		32.5667 ^{iv}	8.4353 ⁱⁱ	+ 13	— .4	—1.7	40 46 34.48	+10 9.59	—1.08	— 28	—18		23.35	—8		
	1		29.8470	14.2003	+186	— .7	—2.1	40 42 59.74	+ 6 35.71	— 12	— 38	—14		23.39	—7	43.2	
	2		9.8020 ⁱⁱ	33.9060 ^{iv}	+ 44	+1.0	+ .3	40 46 33.33	+10 8.98	—1.03	+ 20	—23		23.29	—7	42.6	
	3		6.0847 ^{iv}	31.6813 ^{iv}	— 37	— .2	— .7	40 25 35.38	+10 46.48	+1.23	— 12	+18		23.15	—8		
	4		7.4980 ⁱⁱ	32.9333 ^{iv}	+ 5	—1.5	—3.3	40 25 40.37	+10 42.51	+1.22	— 66	+19		23.63	—8		
	5		0.9127 ⁱⁱ	34.2063 ^{iv}	—191	—1.4	—4.0	40 22 22.13	+14 0 51	+1.34	— 73	+26		23.51	—8		
	6		27.0400	14.9113	+ 70	—2.1	—1.5	40 31 16.52	+ 5 6.54	+ 24	— 52	+10		22.88	—8		
	7		19.2760	22.2503	+ 14	—1.2	—2.6	40 37 38.73	+ 1 15.17	+ 2	— 52	— 2		23.04	—9	42.1	
	X 7	D	14.2883	25.5953	— 4	—3.5	—4.8	40 31 37.79	+ 4 45 61	+ 22	—1.16	+ 9		22.55	—7	43.2	
	8		30.0163	10.2443	+ 10	—1.0	—1.6	40 44 43.60	+ 8 19.47	— 21	— 36	—15		23.41	—7		
Apr. 18	9		27.8867	10.3497	— 91	—3.0	—3.8	40 43 47.28	+ 7 22.76	— 17	— 96	—13		23.26	—7	43.2	
	10		6.7390 ⁱⁱ	30 9000 ^{iv}	— 29	— .4	0	40 46 34.70	+10 10.24	—1.09	— 6	—18		23.13	—8		
	XI 1		10.8250	26.5433	—123	+ .3	+ .4	40 42 59.93	+ 6 36.74	— 12	+ 10	—14		23.03	—7	42.8	
	2		30.0270 ^{iv}	5.9187 ⁱⁱ	— 50	+1.6	+ .1	40 46 33.52	+10 8.85	—1.03	+ 27	—23		23.68	—7	42.7	
	3		32.1607 ^{iv}	6.5737 ⁱⁱ	— 21	—1.5	—1.6	40 25 35.58	+10 46.28	+1.23	— 44	+18		22.83	—8	42.3	

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Apr. 18	XI 4	D	32.4740 ^{iv}	7.0843 ⁱⁱ	-7	-.2	-.1	40 25 40.56	+10 41.84	+1.22	-	5 +19	40 36 23.26	-8	41.9
	5		33.7367 ^{iv}	0.4973 ⁱⁱ	-227	+1.0	+1.0	40 22 22.80	+13 59.06	+1.33	+	28 +26	23.23	-8	41.5
Apr. 23	XI 2	R	13.4480	25.5883	-34	+1.0	+.2	40 31 16.69	+5 6.58	+.24	+	18 +10	23.79	-8	41.2
	3		9.1380 ⁱⁱ	33.2663 ^{iv}	+30	+1.4	-.7	40 46 34.24	-10 9.57	-1.03	+	14 -23	23.55	-7	40.0
			7.3767 ⁱⁱ	32.9147 ^{iv}	+4	+1.1	+.7	40 25 36.39	+10 45.11	+1.22	+	26 +18	23.16	-8	
	4		7.2683 ⁱⁱ	32.6493 ^{iv}	-2	-.4	-1.1	40 25 41.84	+10 41.13	+1.22	-	20 +19	23.68	-8	
	5		1.8883 ⁱⁱ	35.0980 ^{iv}	-117	+.5	+.5	40 22 23.04	+13 58.60	+1.34	+	14 +26	23.38	-8	41.0
	6		26.7877	14.6753	+54	-3.8	-2.7	40 31 17.89	+5 6.10	+.24	+	94 +10	22.89	-8	
Apr. 24	VII 3	R	18.0780	21.1077	-7	-1.4	-.7	40 37 39.60	-1 16.51	+.2	-	32 -2	22.77	-8	40.4
			21.1083	18.1940	-6	+.8	+.9	40 35 9.26	+1 13.60	+.10	+	24 +2	23.22	+3	51.4
	4		24.2553	15.1580	-15	+1.0	+1.3	40 40 12.43	-3 49.75	-	2	32 -8	22.90	+3	50.6
	5		26.8700	9.6177	-179	-.4	-.7	40 29 7.11	+7 15.83	+.29	-	16 +13	22.70	+4	
	6		27.5333	13.0393	+25	+1.4	+1.4	40 43 28.89	-6 6.17	-	14	40 -10	22.88	+3	49.8
	7		25.3900	13.3610	-45	0	-.3	40 41 26.92	-5 3.73	-	11	4 -8	22.96	+3	49.6
	8		18.7850	21.3710	+2	-.4	-1.2	40 37 23.09	-1 5.33	+.1	-	22 -2	22.53	+3	
	9		27.0090	14.6690	+61	0	-.7	40 31 10.69	+5 11.85	+.26	-	9 +12	22.33	+3	
	10		20.2883	21.3737	+5	-.1	-.2	40 36 50.29	-	27.43	+.5	4 -1	22.86	+3	
	VIII 1		22.6843	19.4083	+20	+1.3	+.2	40 37 45.47	-1 22.80	+.1	+	23 -2	22.89	+2	48.8
	2		15.0950	27.2827	+87	+.8	-.3	40 31 14.37	+5 8.07	+.27	+	8 +11	22.90	+2	48.4
	3		14.5170	26.8457	+49	-1.0	-.4	40 41 34.90	-5 11.53	-	11	21 -9	22.96	+2	a
	4		14.5590	22.9180	-63	+.7	+.3	40 32 51.67	+3 30.98	+.17	+	15 +6	23.03	+2	47.6
	5		31.6150 ^{iv}	11.8770 ⁱⁱ	-4	-2.0	-1.8	40 28 3.52	+8 18.56	+1.16	-	54 +17	22.87	+1	
	6		19.6313	22.6663	+20	-1.7	-.6	40 37 39.94	-1 16.71	+.3	-	34 -3	22.89	+1	
	7		11.0533 ⁱⁱ	26.9970 ^{iv}	+23	+.6	-.2	40 29 38.64	+6 42.78	+1.09	+	7 +11	22.69	+1	46.8
	8		21.1203	20.3557	+3	-.9	-.6	40 36 3.10	+.19.32	+.11	-	22 +1	22.32	+1	
	9		27.9647	14.1697	+88	-2.3	-2.0	40 30 34.15	+5 48.67	+.27	-	62 +11	22.58	0	
	10		5.4050 ⁱⁱ	33.1010 ^{iv}	-35	+2.2	+1.1	40 43 2.84	-11 39.48	-1.11	+	49 -24	22.50	0	46.4
Apr. 25	VII 6	D	28.6130	13.2637	+86	+1.0	+.2	40 42 50.97	-6 27.93	-	16	18 -11	22.95	0	46.0
			12.2833	26.7953	-39	+1.0	+.5	40 42 29.02	-6 6.46	-	14	22 -10	22.54	+4	48.3
	7		13.4590	25.5140	-37	+1.7	+2.2	40 41 27.06	-5 4.40	-	11	54 -8	23.01	+3	48.2
	XI 2	D	30.4190 ^{iv}	6.2177 ⁱⁱ	-42	+1.8	+2.2	40 46 34.50	-10 11.24	-1.04	+	56 -23	23.55	-6	41.0
	3		32.4163 ^{iv}	6.8907 ⁱⁱ	-11	-2.0	-1.2	40 25 36.69	+10 44.77	+1.22	-	47 +18	22.39	-8	40.6
	4		31.4093 ^{iv}	6.0507 ⁱⁱ	-40	+.2	-.2	40 25 41.63	+10 40.48	+1.22	0	+19	23.52	-8	
	5		34.4307 ^{iv}	1.2147 ⁱⁱ	-170	-2.9	-2.2	40 22 23.31	-13 58.64	+1.34	+	74 +26	22.81	-8	39.6
	6		12.6103	24.6767	-97	+.1	0	40 31 17.64	+5 4.56	+.24	+	2 +10	22.56	-8	
	7		22.7733	19.7330	+23	-.5	-.7	40 37 39.84	-1 16.86	+.2	-	17 -2	22.81	-8	
	8		20.2313	21.1753	+3	+.3	+.4	40 36 46.37	-	23.85	+.5	10 -1	22.66	-8	
	I 1		23.8343	16.5357	+6	+1.2	+.9	40 33 17.88	+3 4.39	+.16	+	30 +5	22.28	-8	38.2a
	2		25.8817	12.8440	-50	-.1	+.3	40 41 52.33	-5 29.21	-	12	2 -10	22.92	-8	38.0
Apr. 28	VII 4	D	14.7163	23.8650	-39	+3.2	+4.2	40 40 12.77	-3 50.97	-	2	+1.04 -9	22.73	+3	61.1
	5		13.2770	30.4750	+192	+.4	+.2	40 29 7.56	+7 14.86	+.29	+	9 +12	22.92	+4	60.4
	6		12.0063	26.5483	-62	+1.7	+1.8	40 42 29.40	-6 7.14	-	14	50 -10	22.52	+4	
	7		13.4487	25.5310	-36	+1.6	+.9	40 41 27.48	-5 5.07	-	11	37 -8	22.59	+3	59.9
	8		20.9240	18.2960	-6	+1.9	+1.4	40 37 28.69	-1 6.36	+.2	+	48 -2	22.81	+4	59.4
	9		14.7930	27.1147	+69	+.3	-.4	40 31 11.26	+5 11.39	+.26	0	+12	23.03	+3	
	10		19.8907	18.7520	-4	+2.5	+1.4	40 36 50.95	-	28.75	+.4	58 -1	22.81	+3	
	VIII 1		17.3537	20.6773	-20	+.7	+.8	40 37 46.17	-1 23.89	+.1	+	21 -2	22.48	+3	59.0
	2		25.5067	13.3463	-41	+.6	+1.0	40 31 15.04	+5 7.03	+.27	+	22 +11	22.67	+2	
	4		24.5570	16.2133	+19	-2.1	-2.3	40 32 52.48	+3 30.79	+.17	-	62 +6	22.88	+2	58.1
	5		8.6390 ⁱⁱ	28.3417 ^{iv}	+3	+.9	+.4	40 28 4.33	+8 17.64	+1.16	+	20 +17	23.50	+2	57.6
	6		21.3817	18.3140	-3	+.2	0	40 37 40.79	-1 17.47	+.3	+	3 -3	23.35	+2	
	7		27.3417 ^{iv}	11.4307 ⁱⁱ	+16	-.9	-.5	40 29 39.54	+6 41.91	+1.09	-	21 +11	22.44	+1	
	8		20.0020	20.7543	+3	-2.1	-2.0	40 36 3.96	+.19.01	+.11	-	58 +1	22.45	+1	
	9		13.2403	27.0080	+10	-1.0	-.4	40 30 35.02	+5 47.76	+.27	-	21 +11	22.95	+1	56.0
	10		31.8307 ^{iv}	4.1453 ⁱⁱ	-92	-.8	-1.3	40 48 3.73	-11 39.02	-1.11	-	29 -24	23.07	0	56.0

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Apr. 28	VIII 11	D	15.1057	30.4810	+255	-1.1	-.6	40 42 51.97	-6 28.98	-16	-25	-11	40 36 22.47	0	54.5
May 6	VII 7	R	26.6633	14.5963	+44	-.9	-1.2	40 41 28.10	-5 4.90	-11	-30	-8	22.71	+4	54.4
	8		19.4343	22.0700	+11	+.6	+.7	40 37 29.39	-1 6.60	+2	+18	-2	22.97	+4	
	9		26.6337	14.3560	+35	+.7	+.7	40 31 11.93	+5 10.19	+26	+20	+12	22.70	+4	53.4
	10		19.1437	20.2967	-2	-1.0	-.8	40 36 51.80	-29.12	+4	-26	-1	22.45	+4	
	VIII 1		22.6197	19.3027	+19	-.2	-.7	40 37 47.12	-1 23.83	+1	-12	-2	23.16	+4	
	2		14.9793	27.0983	+75	+1.3	+1.9	40 31 15.94	+5 6.29	+27	+44	+11	23.05	+3	52.5
	3		14.1710	26.5607	+26	+.6	+.7	40 41 36.87	-5 13.01	-11	+18	-9	23.84	+3	
	4		16.1910	24.4807	+18	-.7	-1.2	40 32 53.68	+3 29.43	+17	-26	+6	23.08	+3	
	5		32.0417 ^{iv}	12.4197 ⁱⁱ	-.6	+1.1	+1.3	40 28 5.52	+8 15.60	+1.16	+34	+17	22.79	+3	51.0
	6		19.0667	22.2127	+12	+.4	+.5	40 37 42.11	-1 19.50	+3	+13	-3	22.74	+2	
May 7	7		13.7257 ⁱⁱ	29.5737 ^{iv}	-39	+2.1	+1.8	40 29 40.98	+6 40.20	+1.09	+56	+11	22.94	+2	51.2
	8		22.4927	21.8160	+11	-.6	+.2	40 36 5.16	+17.12	+11	-7	+1	22.33	+2	
	9		27.1243	13.4247	+20	+.2	-.7	40 30 36.45	+5 46.08	+27	-6	+11	22.85	+2	50.5
	10		3.5663 ⁱⁱ	31.3400 ^{iv}	-117	+.3	0	40 48 5.23	-11 41.22	-1.12	+5	-24	22.70	+1	50.2
	XI 11		30.6947	15.2903	+273	-1.2	-3.0	40 42 53.70	-6 29.78	-16	-57	-11	23.08	+1	49.0
	2	R	8.1623 ⁱⁱ	32.3707 ^{iv}	+8	-1.8	-3.2	40 46 36.72	-10 11.52	-1.04	-69	-23	23.24	-5	46.1
	3		5.6883 ⁱⁱ	31.1457 ^{iv}	-51	-2.0	-2.4	40 25 39.16	+10 42.91	+1.22	-62	+18	22.85	-7	
	4		8.1000 ⁱⁱ	33.3773 ^{iv}	+24	-1.7	-2.2	40 25 44.02	+10 38.55	+1.22	-54	+19	23.44	-7	
	5		0.0577 ⁱⁱ	33.1947 ^{iv}	-261	+.4	-.9	40 22 25.58	+13 56.36	+1.34	-5	+26	23.49	-7	
	6		27.4563	15.4887	+105	-1.7	-1.6	40 31 19.82	+5 2.56	+24	-47	+10	22.25	-7	
May 8	7		19.3490	22.4720	+17	-1.1	-1.2	40 37 42.02	-1 18.93	+2	-32	-2	22.77	-7	46.7
	8		20.3020	19.2727	0	-1.2	-1.4	40 36 48.45	-26.00	+5	-36	-1	22.13	-8	
	I 1		15.7043	22.9810	-28	-1.4	-2.1	40 33 19.40	+3 3.74	+16	-49	+5	22.86	-8	45.9
	2		13.3083	26.4033	-12	-1.7	-1.3	40 41 54.23	-5 30.75	-12	-44	-10	22.82	-8	45.4
	3		16.2307	22.6707	-21	+.3	+.3	40 33 40.45	+2 42.62	+15	+9	+5	23.36	-8	45.4
	VII 7	D	12.8523	24.9393	-79	-.4	-.1	40 41 28.19	-5 5.09	-11	-8	-8	22.83	+4	54.9
	8		19.9910	17.3357	-23	+1.0	+1.2	40 37 29.48	-1 7.01	+1	+31	-2	22.77	+4	
	9		13.6450	25.9477	-16	+1.0	-.6	40 31 12.02	+5 10.70	+26	+8	+12	23.18	+4	54.2
	10		20.7170	19.5907	0	+.3	-.3	40 36 51.91	-28.45	+4	+1	-1	23.50	+4	
	11		16.7303	20.0703	-33	-.6	-1.0	40 37 47.24	-1 24.29	+1	-22	-2	22.72	+4	52.8
May 9	2		21.7883	14.6403	+52	-1.3	-2.7	40 31 16.07	+5 6.97	+27	-54	+11	22.88	+3	
	3		21.687	12.6650	-84	-.7	-1.6	40 41 37.01	-5 13.54	-11	-31	-9	22.96	+3	51.0
	4		21.6167	16.3467	+23	-1.1	-1.8	40 32 53.84	+3 28.95	+17	-40	+6	22.62	+3	
	5		10.9957 ⁱⁱ	30.6543 ^{iv}	0	-.9	-1.7	40 28 5.65	+8 16.54	+1.16	-36	+17	23.16	+3	
	6		22.4693	19.3447	+17	+1.3	+.3	40 37 42.46	-1 18.97	+3	+24	-3	23.73	+3	
	7		28.7577 ^{iv}	12.8847 ⁱⁱ	-21	-2.6	-1.7	40 29 41.15	+6 40.97	+1.09	-63	+11	22.59	+2	51.4
	8		21.0170	21.7127	+6	+.2	-.2	40 36 5.30	+17.59	+11	0	+1	23.01	+2	
	9		13.8473	27.5357	+57	+1.2	+.3	40 30 36.61	+5 45.89	+27	+23	+11	23.11	+2	50.5
	10		32.8240 ^{iv}	5.0833 ⁱⁱ	-47	+.1	-1.8	40 48 5.40	-11 40.56	-1.12	-21	-24	23.27	+2	50.1
	11		13.6893	29.1337	+128	-.6	-1.7	40 42 53.89	-6 30.42	-16	-31	-11	22.89	+1	50.0
May 10	XI 2	D	31.1057 ^{iv}	6.8860 ⁱⁱ	-25	-2.5	-2.3	40 46 36.90	-10 11.72	-1.04	-68	-23	23.23	-5	45.9
	3		32.0560 ^{iv}	6.5897 ⁱⁱ	-22	-1.7	-1.3	40 25 39.36	+10 43.22	+1.22	-50	+18	23.48	-7	
	4		31.7910 ^{iv}	6.4773 ⁱⁱ	-27	-1.0	-2.0	40 25 44.21	+10 39.35	+1.22	-41	+19	24.56	-7	
	5		36.4177 ^{iv}	3.3087 ⁱⁱ	-11	-1.2	-1.6	40 22 25.76	+13 56.30	+1.34	-39	+26	23.27	-7	
	6		13.8687	25.8550	-10	+.1	-.3	40 31 19.99	+5 2.75	+25	-2	+10	23.07	-7	44.8
	7		21.8693	18.7373	+6	-1.3	-1.6	40 37 42.20	-1 19.13	+2	-40	-2	22.67	-7	
	8		18.3010	19.3223	-6	+.2	+.1	40 36 48.63	-25.78	+5	+4	-1	22.93	-8	44.6
	I 1		23.8763	16.6513	+11	+1.8	+.9	40 33 19.57	+3 2.53	+16	+40	+5	22.71	-8	44.2
	2		24.6207	11.4913	-151	+.6	+.3	40 41 54.40	+5 31.26	-12	+14	-10	23.06	-8	
	3		23.9500	17.5687	+29	+1.0	+1.6	40 33 40.60	+2 41.26	+15	+36	+5	22.42	-8	44.4
May 11	VIII 1	R	21.5007	18.1507	-3	-.1	0	40 37 47.37	-1 24.60	0	-2	-2	22.73	+4	57.2
	2		14.2627	26.3700	+24	+2.1	0	40 31 16.18	+5 5.87	+30	+34	+11	22.80	+3	
	3		13.9670	26.3923	+14	-.5	-.1	40 41 37.16	-5 13.87	-15	-10	-9	22.95	+3	56.6
	4		16.0263	24.2957	+9	+.1	-.4	40 32 54.00	+3 28.90	+19	-4	+6	23.11	+3	

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	δ'	r			
May 8	VIII 5	R	30.8213 ^{iv}	11.1797 ⁱⁱ	- 3	-.6	-.3	40 28 5.81	+ 8 16.10	+1.22	- 14	+17	40 36 23.16	+3	55.6
			18.2240	21.3900	- 4	-.3	-.6	40 37 42.44	- 1 19.95	+ 2	- 12	- 3	22.36	+3	
			12.7587 ⁱⁱ	28.6027 ^{iv}	- 17	+ .1	-.2	40 29 41.33	+ 6 40.14	+1.14	- 1	+11	22.71	+3	54.8
			22.9110	22.2217	+ 10	-.3	-.2	40 36 5.46	+ 17.44	+ 11	- 8	+ 1	22.94	+2	54.4
			28.5193	14.8567	+137	+ .1	+ .3	40 30 36.78	+ 5 45.44	+ 31	+ 6	+11	22.70	+2	
	IX 1	D	5.4107 ⁱⁱ	33.1877 ^{iv}	- 32	-.2	0	40 48 5.58	-11 41.51	-1.20	- 3	-24	22.60	+2	53.6
			25.8373	10.3467	-176	-.4	-1.0	40 42 54.10	- 6 30.81	- 21	- 19	-11	22.78	+2	
			29.1417	13.5093	+121	-.9	-.7	40 29 47.43	+ 6 35.15	+ 33	- 24	+12	22.79	+1	53.4a
			24.9870	17.2667	+ 51	+1.1	+ .8	40 39 38.22	- 3 15.13	- 7	+ 28	- 5	23.25	0	53.3
	IX 2	D	17.3010	23.7163	+ 18	-1.3	-1.6	40 39 5.25	- 2 42.08	- 5	- 40	- 4	22.68	-0	
			19.2617	22.4957	+ 17	-1.0	-.3	40 37 44.01	- 1 21.72	+ 2	- 20	- 3	22.08	-1	52.8
			25.3437	13.2237	- 52	+ .2	-.3	40 31 16.32	+ 5 6.00	+ 30	- 1	+11	22.72	+3	59.6
			26.0080	13.5900	- 15	+ .1	-1.4	40 41 37.32	- 5 13.62	- 15	- 16	- 9	23.30	+4	
			24.7397	16.4883	+ 29	-.3	-.7	40 32 54.17	+ 3 28.49	+ 19	- 14	+ 6	22.77	+3	58.4
May 9	VIII 2	D	7.9040 ⁱⁱ	27.5380 ^{iv}	+ 6	-.2	-1.2	40 28 5.98	+ 8 15.92	+1.22	- 18	+16	23.10	+3	
			22.5053	19.3507	+ 17	-.2	+ .2	40 37 42.62	- 1 19.71	+ 2	0	- 3	22.90	+3	57.6
			28.1392 ^{iv}	12.3067 ⁱⁱ	- 5	-1.3	-1.2	40 29 41.52	+ 6 39.88	+1.14	- 36	+11	22.29	+3	
			20.5777	21.2550	+ 3	-.6	-.4	40 36 5.62	+ 17.12	+ 11	- 24	+ 1	22.62	+2	
			12.6203	26.3097	- 44	-1.4	-.9	40 30 36.97	+ 5 45.66	+ 31	- 34	+11	22.71	+2	
	IX 2	D	30.7657 ^{iv}	2.9860 ⁱⁱ	-142	-.5	-1.7	40 48 5.77	-11 41.30	-1.20	- 30	-23	22.74	+2	55.9
			13.4177	23.8810	+104	-.3	-1.0	40 42 54.32	- 6 30.83	- 21	- 18	-11	22.99	+2	54.6
			16.3567	24.0453	+ 8	-3.5	-4.0	40 39 38.46	- 3 14.22	- 7	-1.06	- 5	23.06	0	
			24.0303	17.6230	+ 30	-.5	-2.2	40 39 5.49	- 2 41.91	- 5	- 36	- 4	23.13	0	53.1
			20.6673	19.3883	0	-2.1	-2.8	40 35 50.98	+ 32.31	+ 8	- 69	+ 1	22.69	0	
	IX 3	D	21.1853	17.9780	- 8	-2.4	-2.6	40 37 44.24	- 1 20.99	+ 2	- 71	- 3	22.53	-1	52.8
			17.6613	19.0063	- 14	-1.8	-2.6	40 36 57.39	- 33.94	+ 7	- 62	- 1	22.89	-1	
			31.3250 ^{iv}	7.3903 ⁱⁱ	- 16	-.6	-.7	40 46 28.92	-10 4.50	-1.15	- 18	-18	22.91	-1	51.9
			22.9530	19.5987	+ 25	+ .7	+2.0	40 37 47.66	- 1 24.78	0	+ 36	- 3	23.21	+4	66.4
			14.9280	27.0510	+ 70	+ .3	+ .1	40 31 16.45	+ 5 6.36	+ 30	+ 6	+11	23.28	+3	65.9
May 10	VIII 1	R	14.2453	26.6437	+ 33	-3.0	-3.1	40 41 37.49	- 5 13.22	- 15	- 86	- 9	23.17	+4	
			17.1353	25.4010	+ 60	-.6	-1.1	40 32 54.34	+ 3 28.92	+ 19	- 24	+ 6	23.27	+4	65.1
			30.3193 ^{iv}	10.6867 ⁱⁱ	0	-1.5	-1.1	40 28 6.15	+ 8 15.85	+1.22	- 38	+17	23.01	+3	64.8
			18.9907	22.1530	+ 11	-.7	-1.9	40 37 42.81	- 1 19.90	+ 2	- 35	- 3	22.55	+3	
			12.2647 ⁱⁱ	28.0880 ^{iv}	- 4	+ .5	+ .4	40 29 41.71	+ 6 39.63	+1.14	+ 13	+11	22.72	+3	
	IX 1	D	20.9447	20.2647	0	+ .5	-.5	40 36 5.80	+ 17.18	+ 11	+ 2	+ 1	23.12	+2	64.1
			28.7693	15.0833	+155	-1.1	-.9	40 30 37.17	+ 5 46.06	+ 31	- 29	+11	23.36	+2	
			5.5113 ⁱⁱ	33.2890 ^{iv}	- 27	-.9	-.5	40 48 5.98	-11 41.50	-1.20	- 21	-23	22.84	+2	62.2
			26.5710	11.0720	-107	-1.4	-2.0	40 42 54.55	- 6 31.18	- 21	- 48	-11	22.57	+2	
			29.6677	14.0477	+171	-.9	-1.4	40 29 47.87	+ 6 34.94	+ 33	- 32	+12	22.94	+1	61.4
	IX 2	D	23.2290	15.5023	- 29	-.6	-.8	40 39 38.70	- 3 15.08	- 7	- 20	- 5	23.30	0	
			17.4573	23.8547	+ 24	-1.7	-1.6	40 39 5.75	- 2 41.64	- 5	- 47	- 4	23.55	0	59.4
			18.9380	20.2020	- 3	-.9	-1.0	40 35 51.24	+ 31.92	+ 8	- 27	+ 1	22.98	0	
			17.4963	20.7197	- 18	-.8	-3.0	40 37 44.48	- 1 21.37	+ 2	- 50	- 3	22.60	-1	59.9
			20.6040	19.2453	0	-.7	-1.4	40 36 57.63	- 34.32	+ 7	- 28	- 1	23.09	-1	
May 11	VIII 7	R	7.8903 ⁱⁱ	31.8253 ^{iv}	- 4	-2.7	-2.5	40 46 29.19	-10 4.51	-1.15	- 74	-18	22.61	-1	59.0
			19.7153	22.8753	+ 24	+ .2	-.3	40 37 43.00	- 1 19.87	+ 1	- 1	- 2	23.11	-7	56.1
			21.5007	20.4580	+ 8	-1.6	-2.9	40 36 49.39	- 26.36	+ 4	- 62	- 1	22.44	-7	
			16.5720	23.8003	+ 8	-.4	-1.2	40 33 20.31	+ 3 2.58	+ 18	- 22	+ 5	22.90	-7	
			13.8487	26.9537	+ 31	-4.0	-1.9	40 41 55.10	- 5 31.08	- 16	- 88	-10	22.88	-8	55.4
	IX 1	D	16.7720	23.2180	0	-2.4	-3.0	40 33 41.26	+ 2 42.81	+ 17	- 76	+ 5	23.53	-8	55.0
			9.9293 ⁱⁱ	34.1410 ^{iv}	+ 52	-1.3	-2.3	40 46 37.68	-10 11.66	-1.11	- 50	-23	24.18	-5	58.4
			6.6143 ⁱⁱ	32.0237 ^{iv}	- 23	-1.4	-1.6	40 25 40.25	+10 41.72	+1.30	- 42	+18	23.03	-6	
			7.8627 ⁱⁱ	33.0940 ^{iv}	+ 15	-.6	-1.3	40 25 45.07	+10 37.31	+1.29	- 26	+19	23.60	-6	
			1.2650 ⁱⁱ	34.3587 ^{iv}	-168	-2.2	-2.0	40 22 26.58	+13 55.44	+1.44	- 60	+26	23.12	-6	57.3
	IX 2	D	27.0500	15.0750	+ 75	-.8	-1.2	40 31 20.78	+ 5 2.64	+ 27	- 28	+10	23.51	-6	
			19.7153	22.8753	+ 24	+ .2	-.3	40 37 43.00	- 1 19.87	+ 1	- 1	- 2	23.11	-7	56.1
			21.5007	20.4580	+ 8	-1.6	-2.9	40 36 49.39	- 26.36	+ 4	- 62	- 1	22.44	-7	
			16.5720	23.8003	+ 8	-.4	-1.2	40 33 20.31	+ 3 2.58	+ 18	- 22	+ 5	22.90	-7	
			13.8487	26.9537	+ 31	-4.0	-1.9	40 41 55.10	- 5 31.08	- 16	- 88	-10	22.88	-8	55.4
	IX 3	D	16.7720	23.2180	0	-2.4	-3.0	40 33 41.26	+ 2 42.81	+ 17	- 76	+ 5	23.53	-8	55.0

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
May 11	I 4	D	22.8077	18.0610	+ 13	-2.0	-1.9	40 34 23.80	+ 1 59.92	+ 14	- 56	+ 3	40 36 23.33	-8	55.2
May 12	VIII 1		17.6217	20.9970	- 15	+ .6	+1.4	40 37 47.92	- 1 25.21	+ 1	+ 27	- 3	22.96	+4	69.3
	2		23.9827	11.8660	-149	- .2	- .1	40 31 16.72	+ 5 5.64	+ 30	- 4	+11	22.73	+4	68.4
	3		25.4617	12.9897	- 57	- .2	- .7	40 41 37.83	- 5 14.84	- 15	- 12	- 9	22.63	+4	
	4		25.0063	16.7697	+ 42	- .8	-1.0	40 32 54.67	+ 3 28.13	+ 19	- 25	+ 6	22.80	+4	67.9
	5		10.6020 ^{II}	30.2143 ^{IV}	0	- .2	- .8	40 28 6.49	+ 8 15.32	+1.22	- 13	+17	23.07	+3	
	6		20.5830	17.4090	- 19	-1.2	+ .4	40 37 43.18	- 1 20.12	+ 2	- 14	- 3	22.91	+3	66.3
	7		27.7487 ^{IV}	11.9270 ^{II}	+ 4	-2.3	-2.2	40 29 42.12	+ 6 39.60	+1.14	- 64	+11	22.33	+3	
	8		21.4780	22.1573	+ 8	-1.6	-2.0	40 36 6.16	+ 17.18	+ 11	- 50	+ 1	22.96	+3	65.4
	9		12.2057	25.8947	- 78	-2.0	-3.0	40 30 37.57	+ 5 45.54	+ 31	- 70	+11	22.83	+2	
	10		32.0523 ^{IV}	4.2320 ^{II}	- 83	+ .5	+ .1	40 48 6.40	-11 42.41	-1.20	+ 10	-23	22.66	+2	
May 19	IX 11		12.8330	28.3297	+ 52	-1.2	-2.6	40 42 55.03	- 6 31.51	- 21	- 52	-11	22.68	+2	63.9
	1		13.8330	27.6887	- 12	- .5	-1.0	40 29 48.33	+ 6 34.10	+ 33	- 20	+12	22.68	+2	63.6
	2		15.0503	22.8333	- 48	+1.7	+2.4	40 39 39.23	- 3 16.44	- 7	+ 57	- 5	23.24	+1	63.5
	3		22.6843	16.2353	- 20	+ .7	+ .1	40 39 6.29	- 2 42.83	- 5	+ 12	- 4	23.49	+1	
	VIII 4		20.2263	18.9613	- 2	- .7	-1.8	40 35 51.80	+ 31.95	+ 8	- 34	+ 1	23.50	+1	62.4
	2	R	13.8807	25.9780	- 6	- .4	- .6	40 31 17.21	+ 5 5.54	+ 30	- 14	+ 3	22.94	+4	58.1
	3		13.8330	26.2790	+ 5	-2.4	-3.2	40 41 33.52	- 5 14.37	- 15	- 78	- 9	23.13	+5	
	5		30.4550 ^{IV}	10.8530 ^{II}	0	0	- .4	40 28 7.26	+ 8 15.10	+1.22	- 5	+17	23.70	+4	56.8
	6		20.3737	23.5530	+ 37	-2.4	-3.3	40 37 44.06	- 1 20.39	+ 2	- 80	- 3	22.86	+4	
	7		11.7143 ^{II}	27.4960 ^{IV}	+ 11	- .3	- .6	40 29 43.11	+ 6 38.64	+1.13	- 12	+11	22.87	+4	
May 31	8		21.9757	21.3457	+ 7	+ .3	- .1	40 36 7.01	+ 15.93	+ 11	+ 4	+ 1	23.10	+3	56.2
	9		28.9080	15.3157	+168	-1.8	-1.9	40 30 38.58	+ 5 43.73	+ 31	- 52	+11	22.21	+3	
	10		4.4593 ^{II}	32.3080 ^{IV}	- 75	+ .4	+ .1	40 48 7.50	-11 43.21	-1.20	+ 8	-23	22.94	+3	56.4
	11		28.8623	13.2940	+ 99	+3.3	+2.1	40 42 56.32	- 6 33.47	- 21	+ 79	-11	23.32	+3	56.5
	IX 1		28.6197	13.0857	+ 79	-2.0	+ .8	40 29 49.61	+ 6 32.55	+ 33	- 22	+12	22.39	+2	
	2		23.5453	15.7063	- 18	+1.2	+ .5	40 39 40.76	- 3 17.95	- 7	+ 26	- 5	22.95	+2	
	3		17.1387	23.6547	+ 15	-1.0	- .6	40 39 7.90	- 2 44.62	- 5	- 24	- 4	22.95	+2	
	4		20.1530	21.2877	+ 4	+1.7	+1.7	40 35 53.48	+ 28.67	+ 8	+ 48	+ 1	22.72	+1	54.8
	5		20.6760	24.0070	+ 45	- .2	+ .6	40 37 46.59	- 1 24.24	+ 2	+ 4	- 3	22.38	+1	54.5
	6		22.6467	21.2150	+ 17	-2.0	-2.2	40 36 59.70	- 36.21	+ 7	- 60	- 1	22.95	0	
	7		8.9667 ^{II}	32.9853 ^{IV}	+ 24	+ .3	-1.0	40 46 31.56	-10 6.72	-1.15	- 8	-18	23.43	0	53.2
May 31	XI 2	D	30.0650 ^{IV}	5.7357 ^{II}	- 54	- .8	-1.7	40 46 39.68	-10 14.39	-1.11	- 34	-24	23.60	-4	49.8
	4		31.8067 ^{IV}	6.6333 ^{II}	- 24	-4.1	-5.6	40 25 47.28	+10 35.79	+1.29	-1.36	+19	23.19	-5	
	5		33.8057 ^{IV}	0.8200 ^{II}	-208	- .7	-1.0	40 22 28.72	+13 52.66	+1.44	- 24	+25	22.83	-5	
	6		13.1870	25.0813	- 61	-1.2	-2.4	40 31 22.87	+ 5 0.28	+ 27	- 49	+10	23.03	-5	49.8
	7		22.1467	18.9150	+ 10	+ .2	- .5	40 37 45.13	- 1 21.66	+ 1	- 4	- 2	23.42	-6	
	8		20.2217	21.3753	+ 5	- .3	- .4	40 36 51.49	+ 29.15	+ 4	- 10	- 1	22.27	-6	
	I 1		23.1273	16.0283	- 18	+ .7	+ .5	40 33 22.38	+ 2 59.27	+ 18	+ 18	+ 5	22.06	-7	
	2		26.8983	13.6387	+ 21	+2.7	+1.1	40 41 57.09	- 5 34.98	- 16	+ 57	-10	22.42	-7	47.6
	4		17.8350	22.5010	+ 4	-1.0	-1.7	40 34 25.69	+ 1 57.87	+ 14	- 38	+ 3	23.35	-7	47.2
	5		17.7057	23.6163	+ 22	+ .8	- .7	40 33 54.12	+ 2 29.36	+ 16	+ 4	+ 4	23.72	-7	
	6		19.1873	20.8890	+ 1	-2.2	-2.2	40 35 41.10	+ 42.99	+ 12	- 62	+ 1	23.60	-7	47.8a
May 31	VIII 6	D	21.9127	18.6653	+ 6	- .5	-1.1	40 37 45.57	- 1 22.03	+ 2	- 22	- 3	23.31	+5	67.0
	7		28.8120 ^{IV}	13.0580 ^{II}	- 24	-2.4	-3.9	40 29 44.78	+ 6 37.82	+1.13	- 87	+11	22.97	+5	65.6
	9		12.7703	26.3447	- 36	-1.7	-3.3	40 30 40.30	+ 5 42.74	+ 31	- 68	+11	22.78	+5	64.7
	10		32.3707 ^{IV}	4.4617 ^{II}	- 73	+ .6	- .2	40 43 9.36	-11 44.69	-1.20	+ 7	-23	23.31	+4	64.4
	11		12.8487	28.4797	+ 62	-1.3	-1.6	40 42 58.54	- 6 34.94	- 21	- 40	-11	22.88	+5	
	IX 1		11.9247	27.3793	- 32	+ .2	+ .2	40 29 51.77	+ 6 30.25	+ 33	+ 6	+12	22.53	+4	63.9
	2		17.3427	25.2393	+ 59	-1.5	-1.5	40 39 43.37	- 3 19.58	- 7	- 43	- 5	23.24	+3	63.4
	3		23.3790	16.7537	+ 3	+ .5	+ .3	40 39 10.60	- 2 47.34	- 5	+ 12	- 4	23.29	+3	63.0
	4		21.9333	20.8910	+ 8	-1.0	- .5	40 35 56.34	+ 26.60	+ 8	- 22	+ 1	22.81	+3	
	5		21.9207	18.4820	+ 4	0	- .3	40 37 50.03	- 1 26.86	+ 1	- 4	- 3	23.11	+2	62.2
	6		19.6980	21.2607	+ 4	- .8	-1.9	40 37 2.33	- 39.48	+ 6	- 36	- 1	22.59	+2	
	7		32.8760 ^{IV}	8.7363 ^{II}	+ 20	+ .3	+1.0	40 46 34.60	-10 9.73	-1.16	+ 18	-18	23.71	+2	61.2

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
June 7	VIII 8	R	21.7437	21.1797	+ 5	— .9	—2.3	40 36 9.08	+ 14.26	+ 11	— 44	+ 1	23.02	+5	67.4
			23.3870	14.8573	+130	— .5	—1.2	40 30 41.04	+ 5 42.03	+ 31	— 23	+11	23.26	+5	65.6
			3.2980 ^{II}	31.2300 ^{IV}	—129	— .4	— .6	40 48 10.17	—11 45.13	—1.20	— 14	—23	23.47	+5	65.3
			28.2743	12.6007	+ 40	— .3	— .6	40 42 59.54	— 6 35.95	— 21	— 12	—11	23.15	+5	
			29.0810	13.6600	+124	—2.6	—2.9	40 29 52.75	+ 6 29.78	+ 33	— 78	+12	22.20	+5	65.1
	IX 1		23.8683	15.8707	— 7	+1.8	+ .8	40 39 44.61	— 3 21.97	— 7	+ 38	— 5	22.90	+4	
			16.1897	22.8610	—18	—1.1	—1.3	40 39 11.91	— 2 48.45	— 5	— 34	— 4	23.03	+4	63.9
			20.0790	21.0760	+ 4	— .6	—1.1	40 35 57.72	+ 25.19	+ 8	— 24	+ 1	22.76	+4	63.3
			19.3697	22.8347	+ 22	— .3	— .5	40 37 50.60	— 1 27.57	+ 1	— 12	— 3	22.89	+3	
			21.8313	20.2277	+ 9	— .3	—2.0	40 37 3.64	— 40.52	+ 6	— 30	— 1	22.87	+3	
			8.2877 ^{II}	32.4893 ^{IV}	+ 10	—1.8	—1.2	40 46 36.11	—10 11.26	—1.16	— 44	—18	23.07	+3	63.0
	XI 6	R	27.2097	15.5263	+ 94	—1.1	—1.5	40 31 27.87	+ 4 55.33	+ 27	— 36	+10	23.21	—3	58.8
			18.7077	22.1347	+ 8	—2.9	—2.8	40 37 50.84	— 1 26.58	0	— 82	— 2	22.92	—3	58.8
			20.3923	19.0943	0	—1.5	—3.2	40 36 56.64	— 32.79	+ 4	— 64	— 1	23.24	—4	58.4
	I 2		13.8943	27.2770	+ 47	—2.4	—1.6	40 42 2.06	— 5 38.13	— 17	— 58	—10	23.08	—4	58.2
			17.5137	23.6683	+ 20	— .5	—1.1	40 33 48.06	+ 2 35.50	+ 16	— 22	+ 4	23.54	—5	
			23.1403	18.6497	+ 23	—3.1	—3.3	40 34 30.47	+ 1 53.48	+ 14	— 91	+ 3	23.21	—5	
			22.0753	16.3227	—28	—2.5	—1.7	40 33 58.79	+ 2 25.23	+ 15	— 61	+ 4	23.60	—5	
			21.3693	19.8510	+ 5	—3.5	—2.3	40 35 45.25	+ 38.36	+ 12	— 84	+ 1	22.90	—5	57.4
			11.5643	31.2347	+162	—2.7	—2.8	40 28 5.97	+ 8 17.23	+ 40	— 78	+16	22.98	—6	
			8.7453 ^{II}	33.4143 ^{IV}	+ 30	— .4	—1.0	40 25 59.16	+10 23.15	+1.29	— 19	+18	23.59	—6	56.6
			15.4950	28.3347	+146	— .5	— .2	40 30 58.40	+ 5 24.67	+ 28	— 10	+ 9	23.34	—6	
			26.4940	15.9777	+ 78	+1.0	+ .7	40 40 49.69	— 4 25.81	— 5	+ 25	—11	23.97	—5	56.4
			11.9743	27.3940	—27	+ .7	+ .6	40 29 52.92	+ 6 29.37	+ 33	+ 18	+12	22.92	+5	68.5
			16.0317	24.0150	0	— .4	— .5	40 39 44.81	— 3 21.63	— 7	— 13	— 5	22.93	+4	67.5
June 8	IX 1	D	23.1670	16.4580	— 7	+1.6	+1.9	40 39 12.12	— 2 49.42	— 5	+ 50	— 4	23.11	+4	67.4
			19.8590	18.8870	— 4	— .1	— .6	40 35 57.96	+ 24.54	+ 8	— 9	+ 1	22.50	+4	67.3
			21.3703	17.8563	+ 7	+2.3	+1.6	40 37 50.83	— 1 28.73	+ 1	+ 56	— 3	22.64	+3	
			18.8667	20.5013	— 2	— .5	— .7	40 37 3.86	— 41.27	+ 6	— 17	— 1	22.47	+3	67.2
			32.3417 ^{IV}	8.1087 ^{II}	+ 6	+ .8	+ .6	40 46 36.37	—10 12.04	—1.16	+ 20	—18	23.19	+3	
	X 1		14.0763	27.0550	+ 43	—1.0	—2.0	40 41 51.00	— 5 27.90	— 16	— 41	—10	22.43	+3	66.4
			8.7703 ^{II}	28.4853 ^{IV}	+ 3	— .2	— .5	40 28 4.19	+ 8 17.92	+1.22	— 10	+16	23.39	+2	65.6
			18.8923	21.1660	0	+ .2	+ .4	40 35 25.47	+ 57.42	+ 10	+ 8	+ 2	23.09	+2	65.6
			12.6433	27.4837	+ 6	— .1	+ .1	40 30 7.26	+ 6 14.82	+ 32	0	+10	22.50	+2	
			30.2187 ^{IV}	8.8697 ^{II}	— 3	+ .2	— .6	40 45 23.77	— 8 59.18	—1.06	— 4	—21	23.28	+1	65.4
			22.3867	18.4177	+ 10	0	+ .2	40 34 42.26	+ 1 40.26	+ 14	+ 2	+ 3	22.71	+1	65.1
			14.9813	25.7473	+ 23	+1.0	+ .3	40 31 51.10	+ 4 31.96	+ 24	+ 20	+ 8	23.58	+1	64.0
			29.7143	9.4127	—54	—1.6	—2.1	40 44 56.55	— 8 32.60	— 28	— 52	—15	23.00	0	62.6
			28.1360	10.0680	—96	— .2	—1.4	40 44 0.12	— 7 36.08	— 23	— 20	—14	23.47	0	
			6.9803 ^{II}	31.6510 ^{IV}	—18	—1.3	—2.3	40 46 47.83	—10 23.03	—1.17	— 50	—18	22.95	—1	61.9
	XI 6	D	12.1607	23.8410	—138	— .3	— .5	40 31 28.17	+ 4 54.66	+ 27	— 12	+10	23.08	—3	61.1
			20.2720	16.8103	—30	— .1	—1.1	40 37 50.65	— 1 27.36	0	— 16	— 3	23.10	—3	60.4
			22.5227	15.5837	—39	—1.4	—3.2	40 33 27.82	+ 2 55.16	+ 18	— 63	+ 5	22.58	—4	60.9
			22.9583	16.8180	— 4	— .6	—1.4	40 33 48.35	+ 2 35.07	+ 16	— 27	+ 4	23.35	—5	60.1
			16.8807	21.3900	—23	—2.1	—4.2	40 34 30.76	+ 1 53.84	+ 14	— 86	+ 3	23.91	—5	59.4
	I 5		17.3583	23.0697	+ 8	— .8	— .3	40 33 59.07	+ 2 24.27	+ 16	— 16	+ 4	23.38	—5	59.3
			18.3590	19.8440	— 7	— .7	—1.1	40 35 45.51	+ 37.49	+ 11	— 25	+ 1	22.87	—5	
			28.6483	8.9970	—136	— .2	—1.7	40 28 6.23	+ 8 15.98	+ 40	— 24	+15	22.52	—5	
			32.4160 ^{IV}	7.7770 ^{II}	+ 3	— .8	— .1	40 25 59.42	+10 22.31	+1.28	— 14	+18	23.05	—6	59.4
			26.1363	13.2997	—21	— .2	— .3	40 30 58.66	+ 5 24.16	+ 28	— 7	+ 9	23.12	—6	59.0
			13.3707	23.9040	—84	—1.2	—3.2	40 40 49.89	— 4 25.83	— 5	— 60	—11	23.30	—5	38.6
	IX 1	R	28.1683	12.7740	+ 42	+1.1	+1.1	40 29 53.09	+ 6 28.89	+ 38	+ 32	+12	22.80	+5	71.9
			24.2237	16.2130	+ 10	+1.5	+1.5	40 39 45.02	— 3 22.33	— 10	+ 43	— 6	22.96	+5	71.3
			16.5687	23.2800	— 3	+ .4	0	40 39 12.34	— 2 49.49	— 7	+ 6	— 5	22.79	+4	71.0
			19.3980	20.3527	+ 1	+ .7	+ .7	40 35 58.19	+ 24.12	+ 8	+ 20	0	22.59	+4	69.5
June 9	10		13.3707	23.9040	—84	—1.2	—3.2	40 40 49.89	— 4 25.83	— 5	— 60	—11	23.30	—5	38.6
	IX 1	R	28.1683	12.7740	+ 42	+1.1	+1.1	40 29 53.09	+ 6 28.89	+ 38	+ 32	+12	22.80	+5	71.9
	2		24.2237	16.2130	+ 10	+1.5	+1.5	40 39 45.02	— 3 22.33	— 10	+ 43	— 6	22.96	+5	71.3
	3		16.5687	23.2800	— 3	+ .4	0	40 39 12.34	— 2 49.49	— 7	+ 6	— 5	22.79	+4	71.0
	4		19.3980	20.3527	+ 1	+ .7	+ .7	40 35 58.19	+ 24.12	+ 8	+ 20	0	22.59	+4	69.5

1893	Patr	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
June 9	IX 5	R	19.0763	22.5790	+ 18	-.5	-.6	40 37 51.05	- 1 28.50	0	- 16	- 3	40 36 22.36	+ 4	68.4
			20.0703	18.4383	- 8	-.5	-1.0	40 37 4.09	- 41.19	+ 6	- 20	- 1	22.75	+ 3	
			8.1177 ^{II}	32.3580 ^{IV}	+ 7	-1.0	-.5	40 46 36.63	-10 12.21	-1.24	- 22	-18	22.78	+ 3	67.4
	X 1		26.7783	13.7693	+ 20	+1.3	+1.4	40 41 51.28	- 5 28.59	- 20	+ 38	- 9	22.78	+ 3	67.2
			32.0857 ^{IV}	12.3773 ^{II}	- 5	-.1	+ .8	40 28 4.44	+ 8 17.73	+1.29	+ 8	+17	23.71	+ 2	
			21.2720	19.0003	+ 2	+1.0	+ .5	40 35 25.74	+ 57.88	+ 11	+ 22	+ 2	23.47	+ 2	67.6
			27.4523 ^{IV}	12.6433 ^{II}	- 1	-.3	-.9	40 30 7.54	+ 6 14.00	+1.18	- 16	+10	22.66	+ 2	67.1
			10.0050 ^{II}	31.3597 ^{IV}	+ 5	-1.1	0	40 45 24.01	- 8 59.34	-1.13	- 18	-21	23.15	+ 2	66.6
			19.3683	23.3450	+ 32	+1.0	+1.3	40 34 42.54	+ 1 40.51	+ 15	+ 32	+ 3	23.55	+ 1	66.4
			25.8140	15.0767	+ 27	-1.0	-1.0	40 31 50.56	+ 4 31.24	+ 28	+ 28	+ 8	22.44	+ 1	66.5
			9.9963	30.2960	+ 19	-.8	-1.5	40 44 56.86	- 8 32.72	- 35	- 32	-14	23.33	0	66.1
			11.0227	29.0617	+ 4	-2.8	-2.3	40 44 0.44	- 7 35.59	- 29	- 74	-14	23.68	0	
			32.4137 ^{IV}	7.7130 ^{II}	+ 1	-2.0	-4.0	40 46 48.16	-10 23.82	-1.25	- 82	-18	22.09	-1	65.1
	XI 6	R	26.7087	15.0627	+ 61	-.8	-.7	40 31 28.48	+ 4 54.29	+ 31	+ 22	+10	22.96	-3	63.4
			18.6153	22.0900	+ 7	+ .9	+ .8	40 37 50.97	- 1 27.78	- 1	+ 24	- 3	23.39	-3	62.9
	I 8		20.8107	19.4663	0	+ .2	-.5	40 36 57.27	- 33.96	+ 3	- 4	- 1	23.29	-4	62.6
			15.9007	22.8393	- 26	+ .3	-.6	40 33 28.15	+ 2 55.18	+ 20	- 2	+ 5	23.56	-4	
			12.5277	25.9607	- 61	-2.2	-1.9	40 42 2.67	- 5 39.12	- 21	- 59	-10	22.65	-4	62.6
			17.5747	23.7047	+ 23	-1.2	-2.9	40 33 48.66	+ 2 34.88	+ 18	- 56	+ 4	23.20	-5	
			21.6847	17.2277	- 15	-2.1	-1.7	40 34 31.07	+ 1 52.53	+ 15	- 55	+ 3	23.23	-5	62.5
			22.8370	17.1357	- 2	-1.9	-1.4	40 33 59.38	+ 2 23.99	+ 18	- 48	+ 4	23.11	-5	61.9
			20.5423	19.0390	0	-2.6	-1.4	40 35 45.78	+ 37.96	+ 12	- 59	+ 1	23.28	-5	
			10.3987	30.0340	+ 24	-1.7	-2.3	40 28 6.52	+ 8 15.98	+ 47	- 56	+15	22.56	-5	60.9
			6.8403 ^{II}	31.4633 ^{IV}	- 23	+ .2	-.7	40 25 59.70	+10 21.83	+1.37	- 6	-18	23.02	-6	
			13.8923	26.7270	+ 22	-.3	-1.7	40 30 58.94	+ 5 24.22	+ 32	- 26	+ 9	23.31	-6	60.8
June 11	IX 10	D	27.3310	16.8160	+128	-1.6	-2.6	40 40 50.12	- 4 25.90	- 9	- 58	-11	23.44	-5	60.5
			12.6123	27.9910	+ 26	+ .6	+ .3	40 29 53.37	+ 6 28.45	+ 38	+ 14	+12	22.46	+5	76.5
			15 5727	23.5323	- 21	-4.0	-3.9	40 39 45.39	+ 3 20.96	- 10	-1.12	- 6	23.15	+5	75.4
			20.8217	14.0940	-100	-.1	-.3	40 39 12.75	- 2 49.66	- 7	- 6	- 5	22.91	+5	74.9
			19.9867	19.0420	- 3	0	-.5	40 35 58.63	+ 23.86	+ 8	- 6	0	22.51	+4	74.2
			20.3433	16.8393	- 29	+ .1	-.5	40 37 51.47	- 1 28.42	0	- 5	- 3	22.97	+4	
			18.1320	19.7853	- 10	-1.0	-1.4	40 37 4.51	- 41.73	+ 6	- 34	- 1	22.49	+3	73.3
			31.9410 ^{IV}	7.6810 ^{II}	- 6	-.2	-.3	40 46 37.11	-10 12.66	-1.24	- 7	-18	22.96	+4	
	X 1		13.4880	26.4967	+ 1	-2.2	-2.8	40 41 51.79	- 5 28.53	- 20	- 70	- 9	22.27	+3	72.3
			9.2520 ^{II}	28.9413 ^{IV}	0	-.2	-.1	40 28 4.93	+ 8 17.25	+1.29	- 4	+17	23.60	+3	
			18.0853	20.3410	- 10	-.8	-.8	40 35 26.28	+ 56.94	+ 11	- 22	+ 2	23.13	+3	
			12.5707 ^{II}	27.3590 ^{IV}	0	+ .1	-.3	40 30 8.11	+ 6 13.47	+1.18	- 2	+10	22.84	+2	
			29.1963 ^{IV}	7.8100 ^{II}	- 12	-.4	-1.7	40 45 24.51	- 9 0.07	-1.13	- 28	-21	22.82	+2	70.4
			21.5700	17.6160	- 10	+ .2	-.5	40 34 43.11	+ 1 39.83	+ 15	- 4	+ 3	23.08	+1	70.0
	XI 6	D	13.0660	24.6877	- 76	+ .9	+ .7	40 31 29.14	+ 4 53.32	+ 31	+ 22	+10	23.09	-2	68.9
June 13	IX 7	R	21.0693	17.5733	- 14	-1.3	-2.3	40 37 51.66	- 1 28.24	- 1	- 50	- 3	22.88	-3	66.6
			28.3190	12.9160	+ 55	-1.6	-1.7	40 29 53.58	+ 6 29.15	+ 38	- 47	+12	22.76	+5	69.5
			23.4197	15.3933	- 28	+ .2	+ .5	40 39 45.70	- 3 22.64	- 10	+ 10	- 6	23.00	+5	68.9
			15.8130	22.5320	- 33	-1.5	-1.3	40 39 13.08	- 2 49.61	- 7	- 40	- 5	22.95	+5	68.6
			19.5333	20.5243	0	+ .4	+ .3	40 35 59.00	+ 23.77	+ 2	+ 10	+ 6	22.95	+5	68.4
			18.7443	22.2450	+ 10	-1.7	-1.2	40 37 51.82	- 1 28.44	0	- 42	- 3	22.93	+4	67.6
			21.9213	20.2893	+ 10	-1.0	-1.7	40 37 4.87	- 41.24	+ 6	- 38	- 1	23.30	+4	67.4
			8.6700 ^{II}	32.9203 ^{IV}	+ 20	-3.0	-1.9	40 46 37.54	-10 12.51	-1.24	- 72	-18	22.89	+4	66.9
	X 1		27.5730	14.5330	+ 82	-.6	-1.2	40 41 52.25	- 5 29.54	- 20	- 24	- 9	22.18	+3	66.6
			30.5930 ^{IV}	10.9057 ^{II}	0	-1.2	-1.7	40 28 5.35	+ 8 17.22	+1.29	- 40	+17	23.63	+3	
			21.5747	19.3277	+ 6	-1.3	-1.1	40 35 26.77	+ 56.75	+ 10	- 34	+ 2	23.30	+3	
			27.1210 ^{IV}	12.3423 ^{II}	+ 10	-1.7	-.3	40 30 8.62	+ 6 13.27	+1.18	- 31	+10	22.86	+3	67.0
			9.6930 ^{II}	31.0853 ^{IV}	+ 2	-2.6	-2.4	40 45 24.94	- 9 0.28	-1.13	- 72	-21	22.60	+2	66.4
			19.8640	22.7950	+ 20	0	-.5	40 34 43.62	+ 1 39.33	+ 15	- 6	+ 3	23.07	+2	
	7		26.3350	15.6623	+ 63	+ .6	+ .2	40 31 52.60	+ 4 29.71	+ 28	+ 12	+ 8	22.79	+1	66.4

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude		Δ	Ther.
						A	B		Micrometer	δ	l	r				
June 13	X	8	R	10.7137	31.0580	+105	-1.1	-.9	40 44 58.04	-8	34.08	-35	-29	-14	40 36 23.18	+1 65.9
		9		12.3917	30.5170	+156	+.5	+.5	40 44 1.64	-7	38.16	-30	+14	-14	23.18	+1 65.4
June 14	I	10		31.5910 ^{iv}	6.8497 ⁱⁱ	-22	-.6	-3.1	40 46 49.44	-10	24.80	-1.25	-48	-8	22.83	0 64.9
		1	D	24.1450	17.3030	+28	0	-.5	40 33 29.83	+2	52.87	+20	-6	+5	22.89	-3 67.6
		2		25.4590	11.9317	-102	+.4	+.2	40 42 4.34	-5	41.39	-21	+9	-10	22.73	-3 66.9
		3		23.5160	17.4730	+17	+.1	+.2	40 33 50.33	+2	32.67	+18	+4	+4	23.26	-4
		4		17.1627	21.5283	-17	-.1	-1.7	40 34 32.72	+1	50.21	+15	-23	+3	22.88	-4 66.6
		5		17.3800	23.0133	+6	+.1	+.2	40 34 1.02	+2	22.29	+18	+4	+4	23.57	-5 66.9
		6		18.5970	20.0103	-6	+.3	0	40 35 47.27	+35.67		+12	+5	+1	23.12	-4
		7		29.6727	10.1053	-14	-.5	-.2	40 28 8.05	+8	14.15	+46	-10	+15	22.71	-5
		8		31.9570 ^{iv}	7.4080 ⁱⁱ	-9	-.3	+.4	40 26 1.28	+10	19.98	+1.36	0	+18	22.80	-5 66.6
		9		27.2553	14.5013	+68	0	+1.3	40 31 0.49	+5	22.28	+32	+16	+9	23.34	-6
June 17	I	10		13.6583	24.2913	-64	+1.1	+1.0	40 40 51.43	-4	28.38	-9	+30	-11	23.15	-5 66.3
		1	R	15.6817	22.5110	-36	-1.0	-1.2	40 33 30.71	+2	52.40	+20	-31	+5	23.05	-3 60.9
		2		13.4490	26.9570	+16	-1.3	-2.5	40 42 5.21	-5	41.21	-21	-52	-10	23.17	-3 61.1
		3		16.7950	22.8210	-7	-.4	-.3	40 33 51.20	+2	32.18	+18	-10	+4	23.50	-3 60.9
		4		22.2400	17.8987	+1	-.3	+.1	40 34 33.60	+1	49.65	+15	-4	+3	23.39	-4
		5		23.0067	17.4190	+6	-.7	-1.6	40 34 1.89	+2	21.14	+17	-31	+4	22.93	-4 60.8
		6		22.8443	21.4613	+17	-1.7	-.8	40 35 48.06	+34.98		+12	-37	+1	22.80	-4
		7		11.7253	31.2367	+171	+2.2	+1.4	40 28 8.87	+8	13.22	+46	+52	+15	23.22	-4
		8		8.7780 ⁱⁱ	33.8047 ^{iv}	+29	+.5	-.8	40 26 2.14	+10	19.54	+1.36	-2	+18	23.20	-5
		9		13.4150	26.1447	-16	+1.2	+.4	40 31 1.35	+5	21.47	+32	+24	+9	23.47	-5 60.6
		10		26.8893	16.2657	+100	+.8	+1.5	40 40 52.13	-4	28.57	-9	+32	-11	23.68	-5
		1	II	21.8517	22.1893	+5	-.6	0	40 36 31.44	-8.54		+12	-10	0	22.92	-5
		2		22.2000	22.4437	+3	+2.0	+2.8	40 36 16.49	+6.16		+10	+68	0	23.43	-5 60.6
June 20	IX	3		29.7107	11.8367	+82	-1.0	-.2	40 28 50.87	+7	31.65	+43	-18	+13	22.90	-6 61.1
		4	D	20.6523	24.4223	+56	+1.3	+1.9	40 37 57.42	-1	35.36	+2	+44	-3	22.49	-6 60.9
		3		23.5623 ^{iv}	16.7420 ⁱⁱ	-393	+.6	+1.1	40 39 14.04	-2	51.24	-8	+24	-5	22.91	+6 83.8
		5		20.2863	16.6983	-32	-.3	+.2	40 37 53.58	-1	30.52	0	-2	-3	23.01	+5 84.4
		6		18.6320	20.3310	-5	-1.0	-1.9	40 37 5.93	-42.89		+6	-40	-1	22.69	+4
		7		32.7687 ^{iv}	8.4620 ⁱⁱ	+16	0	+.6	40 46 38.77	-10	13.85	-1.24	+8	-18	23.58	+5 83.9
		1	X	13.6043	26.7057	+12	+.5	+1.0	40 41 53.64	-5	30.88	-20	+20	-9	22.67	+4
		2		9.3763 ⁱⁱ	28.9913 ^{iv}	0	-.2	-.4	40 28 6.59	+8	15.33	+1.29	-8	+17	23.30	+4 83.4
		3		19.0643	21.2557	+2	-.3	-.1	40 35 23.17	+55.34		+10	-6	+2	23.57	+4
		4		12.9447	27.6500	+27	+.1	0	40 30 10.12	+6	11.42	+37	+2	+10	22.03	+4 83.5
		5		30.3617 ^{iv}	8.9107 ⁱⁱ	-3	+1.5	+.9	40 45 26.17	-9	1.69	-1.13	+36	-21	23.50	+3 83.2
		6		22.0080	18.1397	+1	-.1	+.3	40 34 45.11	+1	37.68	+15	+2	+3	22.99	+3 82.7
		7		14.3770	25.0233	-18	+.2	-1.3	40 31 54.27	+4	28.81	+28	-14	+8	23.30	+2
		8		30.3980	9.9543	+22	+.9	+1.1	40 44 59.71	-8	36.27	-35	+28	-14	23.23	+2
		9		29.4010	11.1743	+31	+1.0	+1.8	40 44 3.34	-7	40.35	-30	+38	-14	22.93	+2 82.0
June 23	IX	10		6.9473 ⁱⁱ	31.7627 ^{iv}	-18	-.3	-.3	40 46 51.26	-10	26.61	-1.25	-9	-18	23.13	+1 80.8
		3	R	16.2863	23.0393	-13	-3.1	-2.8	40 39 14.58	-2	50.52	-8	-85	-4	23.09	+6 69.3
		4		18.9463	19.8590	-4	-2.5	-3.6	40 36 0.65	+23.04		+8	-85	0	22.92	+6 68.3
		5		19.3293	22.8783	+23	-1.8	-3.8	40 37 53.41	-1	29.69	0	-76	-3	23.93	+5
		6		22.4823	20.7810	+16	-1.9	-3.7	40 37 6.50	-43.00		+6	-76	-1	22.79	+5
		7		8.7083 ⁱⁱ	33.0237 ^{iv}	+22	-1.9	-3.3	40 46 39.43	-10	14.13	-1.24	-72	-18	23.16	+5 67.1
		1	X	26.9540	13.8340	+32	+.4	0	40 41 54.29	-5	31.44	-20	+6	-9	22.62	+5 66.4
		2		31.1440 ^{iv}	11.5647 ⁱⁱ	-4	+1.8	+.6	40 28 7.25	+8	14.48	+1.29	+36	+16	23.54	+4
		3		22.4313	20.3107	+17	+1.8	+2.9	40 35 23.91	+53.60		+10	+65	+2	23.28	+4
		4		27.8917 ^{iv}	13.2423 ⁱⁱ	-17	+1.2	+1.2	40 30 10.89	+6	9.94	+1.18	+34	+10	22.45	+4
		5		10.4913 ⁱⁱ	31.9447 ^{iv}	+9	-2.1	-1.6	40 45 26.84	-9	1.84	-1.13	-54	-21	23.12	+3 65.9
		6		19.5380	23.3507	+32	+2.2	+1.9	40 34 45.88	+1	36.37	+15	+59	+3	23.02	+3 65.1
		7		26.3043	15.7270	+63	+1.5	+1.3	40 31 55.13	+4	27.30	+27	+40	+8	23.18	+3 66.4
		8		10.6707	31.1373	+109	-.1	+3.7	40 45 0.55	-8	37.18	-35	+45	-14	23.33	+2
		9		11.1797	29.4040	+31	-.5	0	40 44 4.20	-7	40.35	-30	-8	-14	23.33	+2 66.2

1898	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
June 23	X I	10 R	33.2763 ^{iv}	8.4173 ⁱⁱ	+ 25	+1.3	+ .1	40 46 52.17	-10 27.89	-1.25	+ 22	-19	40 36 23.06	+2 66.1	
		4 D	18.0063	22.2930	+ 4	-1.7	-1.8	40 34 35.36	+ 1 48.28	+ 15	- 50	+ 3	23.32	-3 62.5	
		5	17.8153	23.3337	+ 19	+ .4	+ .6	40 34 3.63	+ 2 19.42	+ 17	+ 14	+ 4	23.40	-3 62.6	
		6	18.0663	19.4287	- 9	-1.4	-3.2	40 35 49.62	+ 34.39	+ 12	- 63	+ 1	23.51	-3	
		8	31.6207 ^{iv}	7.1690 ⁱⁱ	- 16	- .6	- .6	40 26 3.82	+10 17.52	+1.36	- 17	+18	22.71	-4 61.5	
June 24	II IX	9	26.5480	13.9097	+ 17	+ .8	+1.4	40 31 3.00	+ 5 19.24	+ 31	+ 30	+ 9	22.94	-4	
		10	14.2050	24.8890	- 29	-2.5	-2.4	40 40 53.46	- 4 29.77	- 9	- 70	-11	22.79	-4 62.1	
		1	19.4183	19.0180	0	+1.5	+ .3	40 36 32.75	- 10.11	+ 12	+ 28	0	23.04	-4 61.2	
		2	19.2223	19.0240	0	- .3	0	40 36 17.83	+ 5.01	+ 10	- 5	0	22.89	-5 60.8	
		3 D	22.0947	15.3017	- 53	- .7	0	40 39 14.75	- 2 51.43	- 8	- 11	- 4	23.09	+6 70.4	
June 28	X I	4	21.0437	20.1627	+ 3	+ .6	+ .5	40 36 0.85	+ 22.26	+ 8	+ 16	0	23.35	+6	
		5	21.5587	17.9527	- 4	+1.0	+ .3	40 37 53.57	- 1 31.06	0	+ 20	- 3	22.68	+5 69.4	
		6	18.5973	20.3283	- 5	- .5	-1.5	40 37 5.94	- 43.70	+ 6	- 27	- 1	22.02	+5	
		7	32.4180 ^{iv}	8.0760 ⁱⁱ	+ 7	- .2	-1.1	40 46 39.65	-10 14.79	-1.24	- 17	-18	23.27	+5 67.8	
		1	14.3093	27.4360	+ 68	+ .6	0	40 41 54.53	- 5 31.69	- 20	+ 10	- 9	22.65	+5 67.6	
June 28	II I	3	18.5103	20.6667	- 5	+ .3	- .3	40 35 29.16	+ 54.45	+ 10	+ 1	+ 2	23.74	+4 67.4	
		4	12.8460 ⁱⁱ	27.0160 ^{iv}	+ 11	+ .1	+ .4	40 30 11.15	+ 6 10.53	+1.18	- 6	+10	23.02	+4	
		5	30.2443 ^{iv}	8.7633 ⁱⁱ	- 5	- .6	-1.1	40 45 27.07	- 9 2.50	-1.13	- 24	-21	22.99	+3 66.8	
		6	21.0077	17.1453	- 22	-1.6	-2.5	40 34 46.15	+ 1 37.49	+ 15	- 57	+ 3	23.25	+3 66.6	
		7	15.1433	25.7557	+ 28	-2.3	-3.2	40 31 55.42	+ 4 28.10	+ 28	- 77	+ 8	23.11	+3 65.9	
June 28	I I	8	29.8363	9.3560	- 50	- .8	- .3	40 45 0.85	- 8 37.11	- 35	- 16	-14	23.09	+3	
		9	29.8647	11.1307	+ 28	-1.7	-2.6	40 44 4.50	- 7 40.58	- 30	- 60	-14	22.88	+2 65.1	
		10	6.4433 ⁱⁱ	31.2977 ^{iv}	- 33	-2.1	-3.3	40 46 52.49	-10 27.63	-1.25	- 75	-19	22.67	+2 64.6	
		5 R	22.9583	17.4777	+ 6	-1.5	-2.5	40 34 5.35	+ 2 18.44	+ 17	- 56	+ 4	23.44	-3 54.8	
		6	22.6363	21.8697	+ 15	- .2	- .7	40 35 51.17	+ 32.03	+ 11	- 12	+ 1	23.20	-2 54.6	
June 30	II I	7	11.5000	30.9350	+139	-1.5	-2.4	40 28 12.10	+ 8 11.24	+ 46	- 54	+15	23.41	-3	
		8	9.3090 ⁱⁱ	33.7343 ^{iv}	+ 40	-1.7	-2.6	40 26 5.50	+10 17.04	+1.36	- 60	+18	23.48	-3 54.6	
		9	15.1450	27.7253	+107	+1.3	+1.3	40 31 4.67	+ 5 18.02	+ 31	+ 37	+ 9	23.46	-4	
		10	27.4343	16.7430	+132	-1.6	-2.0	40 40 54.86	- 4 30.37	- 9	- 50	-11	23.79	-4	
		1	21.6243	22.0480	+ 6	-1.3	-1.3	40 36 34.14	- 10.72	+ 12	- 37	0	23.17	-4 54.2	
June 30	I I	2	21.4737	21.6243	0	+ .3	0	40 36 19.26	+ 3.80	+ 10	+ 5	0	23.21	-4	
		3	30.0330	12.2637	+119	-2.0	-1.9	40 28 53.74	+ 7 29.12	+ 43	- 56	+14	22.87	-5 53.6	
		4	21.1680	25.0107	+ 70	- .9	- .7	40 38 0.07	- 1 37.23	+ 2	- 24	- 3	22.59	-5	
		5	30.5647 ^{iv}	12.2340 ⁱⁱ	- 13	-1.0	0	40 28 38.98	+ 7 42.97	+1.24	- 16	+13	23.16	-5 53.2	
		6	9.9397 ⁱⁱ	30.7207 ^{iv}	0	- .5	-1.5	40 27 36.87	+ 8 44.88	+1.28	- 27	+14	22.90	-6 52.8	
June 30	I I	7	29.7860 ^{iv}	13.3887 ⁱⁱ	- 34	- .2	+ .1	40 29 27.22	+ 6 54.07	+1.19	- 2	+12	22.58	-6 53.1	
		8	14.1653	28.7677	+126	+1.3	+2.3	40 42 32.49	- 6 9.15	- 22	+ 50	-10	23.52	-6 52.9	
		5 D	17.9690	23.3910	+ 23	+1.0	0	40 34 5.96	+ 2 17.01	+ 17	+ 16	+ 4	23.34	-2 60.1	
		6	19.4397	20.6543	+ 1	+1.2	+1.9	40 35 51.73	+ 30.68	+ 11	+ 43	+ 1	22.96	-2 60.3	
		7	30.6453	11.2793	+110	- .9	- .7	40 28 12.69	+ 8 9.41	+ 46	- 24	+15	22.47	-3	
July 2	X I	8	33.0570 ^{iv}	8.7030 ⁱⁱ	+ 23	- .2	+1.0	40 26 6.11	+10 15.17	+1.36	+ 10	+18	22.92	-3 60.1	
		9	28.1040	15.5843	+136	+2.4	+1.2	40 31 5.29	+ 5 16.56	+ 31	+ 53	+ 9	22.78	-3	
		10	14.6523	25.4370	+ 3	+1.4	+1.6	40 40 55.37	- 4 32.40	- 9	+ 42	-11	23.19	-3 60.2	
		1	19.5570	19.0677	0	+2.1	+1.5	40 36 34.66	- 12.36	+ 12	+ 52	0	22.94	-3	
		2	19.8407	19.7203	0	+ .8	- .2	40 36 19.57	+ 3.04	+ 10	+ 10	0	22.81	-4	
July 2	X I	3	11.0717	28.8040	- 5	+ .6	- .9	40 28 54.31	+ 7 27.85	+ 43	- 2	+14	22.71	-4 59.26	
		4	21.1603	17.2820	- 19	- .1	- .3	40 38 0.60	- 1 37.92	+ 2	- 6	- 3	22.61	-4	
		5	11.1793 ⁱⁱ	29.4767 ^{iv}	+ 0	+ .3	+ .9	40 28 39.54	+ 7 42.14	+1.24	+ 16	+13	23.21	-5 58.6	
		6	30.3803 ^{iv}	9.6393 ⁱⁱ	0	- .4	- .5	40 27 37.42	+ 8 43.86	+1.28	- 13	+14	22.57	-5 58.6	
		7	12.2943 ⁱⁱ	28.6723 ^{iv}	- 11	+2.2	+1.6	40 29 27.77	+ 6 53.64	+1.19	+ 55	+12	23.27	-6	
July 2	X I	8	26.9360	12.2847	- 33	+2.4	+1.4	40 42 33.01	- 6 9.96	- 22	+ 56	-10	23.29	-6 58.6	
		1	27.1200	13.9180	+ 39	+ .9	+ .5	40 41 55.87	- 5 33.52	- 26	+ 20	-10	22.19	+6 73.3	
		2	31.4833 ^{iv}	11.9830 ⁱⁱ	- 5	+ .6	+ .3	40 28 8.74	+ 8 12.60	+1.36	+ 14	+16	23.00	+5	
		3	22.1057	20.0393	+ 13	+ .6	+2.2	40 35 30.62	+ 52.22	+ 11	+ 38	+ 2	23.35	+5 73.1	
		4	28.5743 ^{iv}	13.9883 ⁱⁱ	- 41	+1.4	+3.0	40 30 12.72	+ 6 8.26	+1.23	+ 60	+10	22.91	+5	

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.			
						A	B		Micrometer	δ	l	r						
July 2	X	5	R	10.6040 ^{II}	32.1407 ^{IV}	+ 11	— .1	+ .9	40 45 28.38	— 9	3.94	—1.22	+	10	—21	40 36 23.11	+4	72.0
		6		19.7380	23.4900	+ 36	+ .9	+1.0	40 34 47.77	+ 1	34.85	+ 16	+ 26	+ 3	23.07	+4	71.3	
		7		26.7347	16.2197	+ 91	— .3	—2.1	40 31 57.27	+ 4	25.79	+ 32	— 32	+ 8	23.14	+4	71.2	
		8		10.2417	30.8210	+ 64	+ .9	+2.6	40 45 2.71	— 8	39.90	— 43	+ 47	—16	22.69	+3		
		9		12.0870	30.4140	+136	+ .9	+1.8	40 44 6.42	— 7	43.20	— 37	+ 37	—14	23.08	+3	71.4	
	XI	10		32.8347 ^{IV}	7.8677 ^{II}	+ 12	+2.1	— .4	40 46 54.59	—10	30.58	—1.35	+	28	—19	22.75	+3	
		1		30.4047	14.0477	+215	0	—2.1	40 43 17.62	6	53.64	— 29	— 27	—15	23.27	+2	69.6	
		2		8.9947 ^{II}	33.7710 ^{IV}	+ 40	— .8	— .6	40 46 50.78	—10	25.83	—1.29	— 20	—24	23.22	+2	68.6	
		3		8.9437 ^{II}	33.7173 ^{IV}	+ 38	+2.0	+3.2	40 25 55.51	+10	25.76	+1.46	+ 72	+18	23.63	+2	68.4	
		4		7.0167 ^{II}	31.6500 ^{IV}	— 18	+ .6	+ .8	40 26 0.09	+10	22.07	+1.46	+ 20	+18	24.00	+1	69.4	
July 5	I	5		2.4960 ^{II}	34.9680 ^{IV}	— 93	+1.9	+3.2	40 22 41.24	+13	39.85	+1.66	+	70	+25	23.70	+1	
		6		26.8447	15.4897	+ 79	+ .6	+2.3	40 31 35.20	+ 4	46.97	+ 34	+ 39	+10	23.00	+1		
		7		19.1687	22.9393	+ 23	+ .8	+1.4	40 37 58.11	— 1	35.28	— 3	+ 30	— 3	23.07	0	69.5	
		8		22.6033	20.9513	+ 18	+1.1	— .3	40 37 4.51	— 4	41.76	+ 3	+ 13	— 1	22.90	0		
		1		17.8053	24.4633	+ 45	—1.0	—1.9	40 33 35.40	+ 2	48.26	+ 22	— 40	+ 5	23.53	0	68.6	
	II	6	R	21.9923	20.8333	+ 9	+2.0	+1.3	40 35 53.02	+	29.55	+ 12	+	48	+ 1	23.18	—2	69.3
		7		11.2987	30.5943	+108	+1.3	+ .3	40 28 14.06	+ 8	7.59	+ 53	+ 24	+15	22.57	—2		
		8		8.1627 ^{II}	32.4820 ^{IV}	+ 9	+1.9	+ .5	40 26 7.55	+10	14.22	+1.45	+ 36	+18	23.76	—2	67.9	
		9		15.0097	27.5170	+ 91	+1.2	+1.4	40 31 6.73	+ 5	16.11	+ 36	+ 36	+ 8	23.64	—3	67.7	
		10		28.2990	17.5080	+186	— .1	+ .3	40 40 56.54	— 4	33.00	— 13	+ 2	—12	23.31	—3	67.8	
July 7	X	1		22.5587	23.0617	+ 8	+ .3	+1.4	40 36 35.83	— 12.73	+ 12	+	22	0	23.44	—3		
		2		22.8630	22.9290	0	+ .4	+ .4	40 36 20.96	+	1.67	+ 10	+ 11	0	23.84	—3	67.8	
		3		30.2183	12.5317	+142	—1.5	—1.9	40 28 55.58	+ 7	27.05	+ 50	— 47	+14	22.80	—4	67.76	
		4		19.3120	23.2320	+ 31	—1.3	0	40 38 1.78	— 1	39.08	+ 1	— 20	— 3	22.48	—4	67.9	
		6		9.5040 ^{II}	30.1910 ^{IV}	0	+1.8	+1.0	40 27 38.68	+ 8	42.46	+1.36	+ 40	+15	23.05	—5	67.4	
	II	7		28.9993 ^{IV}	12.6640 ^{II}	— 20	+1.2	+ .6	40 29 29.00	+ 6	52.50	+1.27	+	26	+12	23.15	—5	
		8		15.0347	29.6753	+204	+ .3	+1.9	40 42 34.17	— 6	10.27	— 23	+ 28	—11	23.84	—5	66.9	
		1	D	14.1410	27.3387	+ 57	— .9	—2.2	40 41 56.78	— 5	33.44	— 26	— 42	—10	22.56	+6	72.0	
		2		9.8157 ^{II}	29.3097 ^{IV}	0	— .4	—1.2	40 28 9.59	+ 8	12.31	+1.36	— 22	+16	23.20	+6		
		3		19.1900	21.2513	+ 3	— .4	—1.5	40 35 31.59	+	52.07	+ 11	— 25	+ 2	23.54	+6	71.9	
July 9	X	4		12.8797 ^{II}	27.4553 ^{IV}	— 6	+ .1	+ .3	40 30 13.75	+ 6	8.09	+1.23	+	6	+10	23.23	+6	
		5		30.8040 ^{IV}	9.2333 ^{II}	0	+ .4	0	40 45 29.25	— 9	4.76	—1.21	+	6	—21	23.13	+5	71.9
		6		22.2947	18.5907	+ 11	+ 3	+1.1	40 34 48.84	+ 1	33.57	+ 16	+ 18	+ 3	23.78	+5	72.0	
		7		15.1987	25.6657	+28	+ .6	0	40 31 58.47	+ 4	24.41	+ 31	+ 10	+ 8	23.37	+5		
		8		30.1657	9.5700	— 17	0	— .4	40 45 3.90	— 8	40.10	— 41	— 5	—16	23.18	+4	71.9	
	D	9		29.8167	11.4430	+ 67	+ .1	— .4	40 44 7.65	— 7	44.19	— 37	— 4	—14	22.91	+4	71.9	
		1	R	27.2673	14.0463	+ 53	+ .5	+ .1	40 41 57.12	— 5	34.03	— 26	+ 9	—10	22.82	+7	71.8	
		2		30.3357 ^{IV}	10.8540 ^{II}	0	+ .4	+1.3	40 28 9.92	+ 8	12.01	+1.36	+ 22	+16	23.67	+6	72.4	
		3		21.5233	19.4320	+ 5	— .6	—1.8	40 35 31.97	+	51.57	+ 11	— 32	+ 2	23.35	+6		
		4		28.4437 ^{IV}	13.8733 ^{II}	— 37	—1.8	— .5	40 30 14.16	+ 6	7.89	+1.23	— 34	+10	23.04	+6		
July 11	D	5		9.3473 ^{II}	30.8893 ^{IV}	0	—1.3	—2.2	40 45 29.61	— 9	4.05	—1.22	— 48	—21	23.65	+5	70.1	
		6		21.7017	17.9713	— 4	— .7	—1.3	40 34 49.27	+ 1	34.20	+ 16	— 28	+ 3	23.38	+5	69.0	
		7		15.3583	25.8387	+ 35	—1.9	—3.7	40 31 58.96	+ 4	24.77	+ 32	— 76	+ 8	23.37	+5		
		8		29.8523	9.2583	— 56	—1.1	—2.0	40 45 4.40	— 8	39.97	— 43	— 42	—16	23.42	+5		
		9		29.2620	10.8830	+ 7	+ .9	+1.1	40 44 8.17	— 7	44.19	— 37	+ 28	—14	23.75	+4	68.8	
	XI	10		7.8480 ^{II}	32.8757 ^{IV}	+ 10	+ .2	— .2	40 46 56.49	—10	32.11	—1.35	0	—19	22.84	+4	67.6	
		1		11.3877	27.8567	— 35	+ .4	+ .6	40 43 19.37	— 6	55.84	— 29	+ 14	—15	23.23	+3	67.8	
		2		31.4710 ^{IV}	6.5753 ^{II}	— 28	+1.1	+1.2	40 46 52.56	—10	28.68	—1.30	+ 32	—24	23.66	+3	67.0	
		3		33.2730 ^{IV}	8.5813 ^{II}	+ 28	+1.8	+1.6	40 25 57.60	+10	23.67	+1.46	+ 48	+18	23.39	+3	67.8	
		4		32.9073 ^{IV}	8.4010 ^{II}	+ 17	+3.6	+3.4	40 26 2.19	+10	18.95	+1.46	+1.00	+18	23.78	+2		
July 13	I	5		32.9877 ^{IV}	0.5640 ^{II}	—237	— .6	+ .3	40 22 43.32	+13	38.27	+1.66	— 6	+25	23.44	+2	67.6	
		6		14.1247	25.4313 ^I	— 17	— .6	—1.0	40 31 37.26	+ 4	45.51	+ 34	— 22	+10	22.99	+2		
		7		22.7420	18.8887	+ 19	+ .5	— .8	40 38 0.32	— 1	37.36	— 3	— 2	— 3	22.88	+1		
		8		19.6200	21.3637	+ 4	—2.0	— .4	40 38 6.66	— 44.05	+ 2	— 36	— 1	22.26	+1	67.6		
		1		23.4930	16.9770	+ 10	+ .2	+ .2	40 33 37.66	+ 2	44.59	+ 21	+	6	+ 5	22.57	+1	66.6

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
July 9	I	D	19.6533	20.8070	0	— .3	— .3	40 35 54.30	+ 29.14	+ 12	— 8	+ 1	23.49	—1	65.1
			29.5663	10.2850	— 8	—1.6	—1.5	40 28 15.39	+ 8 6.95	+ 53	— 44	+15	22.58	—2	
			32.8947 ^{iv}	8 6327 ⁱⁱ	+ 20	+3.3	+4.0	40 26 8.94	+10 11.56	+1.45	+1.02	+18	23.15	—2	64.6
			26.9150	14.4367	+ 47	—1.9	—1.5	40 31 8.11	+ 5 15.28	+ 36	— 48	+ 8	23.35	—2	
			13.0993	23.9783	— 95	+ .2	0	40 41 57.69	— 4 34.52	— 13	+ 3	—12	22.95	—2	
	II		20.3340	19.7817	0	+ .5	0	40 36 36.98	— 13.95	+ 12	+ 8	0	23.23	—2	64.5
			20.0617	20.0243	0	— .3	— .7	40 36 22.14	+ 0.94	+ 10	— 14	0	23.04	—3	64.6
			10.5847	28.1950	— 67	— .1	—1.1	40 28 56.82	+ 7 25.86	+ 49	— 16	+14	23.15	—3	
			21.2237	17.2670	— 19	— .7	—2.0	40 38 2.93	— 1 39.89	0	— 36	— 3	22.65	—3	
			11.9113	30.1110	+109	— .1	— .4	40 28 42.05	+ 7 39.93	+ 50	— 6	+13	22.55	—4	63.6
July 10	III	X	30.0493 ^{iv}	9.3653 ⁱⁱ	0	—2.8	—2.1	40 27 39.88	+ 8 42.40	+1.36	— 70	+15	23.09	—4	
			28.0423	13.3577	+ 60	— 0	— .6	40 42 35.28	— 6 11.03	— 28	— 8	—11	23.78	—5	62.8a
			17.3677	25.1443	+ 57	— .8	— .9	40 39 40.23	— 3 16.55	— 13	— 24	— 5	23.26	—5	63.0
			27.0117	13.7987	+ 31	—1.2	—1.3	40 41 57.26	— 5 33.78	— 26	— 35	—10	22.77	+7	65.8
			31.6203 ^{iv}	12.1177 ⁱⁱ	— 5	—2.2	—2.1	40 28 10.06	+ 8 12.55	+1.36	— 61	+16	23.52	+6	65.8
	XI		23.3857	21.3243	+ 30	—2.0	—1.6	40 35 32.12	+ 52.14	+ 11	— 52	+ 2	23.87	+6	
			27.9373 ^{iv}	13.3770 ⁱⁱ	— 23	—3.3	—2.4	40 30 14.34	+ 6 7.68	+1.23	— 82	+10	22.53	+6	65.1
			12.4700 ⁱⁱ	34.0323 ^{iv}	+ 29	—1.0	— .8	40 45 29.76	— 9 4.65	—1.22	— 26	—21	23.42	+5	65.1
			19.9010	23.5767	+ 39	+ .7	+ .5	40 34 49.46	+ 1 32.94	+ 16	+ 18	+ 3	23.77	+5	65.0
			24.5070	14.0523	— 43	+ .3	— .3	40 31 59.18	+ 4 23.93	+ 31	0	+ 8	23.50	+5	
	I	II	9.6480	30.2830	— 4	— .1	0	40 45 4.63	— 8 41.15	— 44	— 2	—16	22.86	+5	65.3
			9.5783	27.9903	—132	—1.5	— .6	40 44 8.41	— 7 44.69	— 37	— 30	—14	22.91	+5	65.1
			32.5916 ^{iv}	7.5593 ⁱⁱ	0	— .8	—1.6	40 46 56.75	—10 32.20	—1.35	— 33	—19	22.68	+4	
			29.5880	13.1247	+130	+ .1	— .2	40 43 19.62	— 6 56.13	— 30	— 1	—15	23.03	+3	64.1
			8.8467 ⁱⁱ	33.6790 ^{iv}	+ 37	—1.3	—1.6	40 46 52.82	—10 27.26	—1.30	— 40	—24	23.62	+3	63.4
	II	R	7.4280 ⁱⁱ	32.1093 ^{iv}	— 8	+1.8	+2.1	40 25 57.93	+10 23.33	+1.46	+ 55	+18	23.45	+3	
			6.9580 ⁱⁱ	31.4873 ^{iv}	— 20	+ .2	+1.8	40 26 2.50	+10 19.46	+1.46	+ 26	+18	23.86	+3	63.5
			2.8760 ⁱⁱ	35.2710 ^{iv}	— 67	+ .9	+ .3	40 22 43.63	+13 38.01	+1.66	+ 18	+25	23.73	+2	
			25.2790	13.9863	— 25	—1.8	—1.0	40 31 37.57	+ 4 45.15	+ 34	— 40	+10	22.76	+2	
			17.3310	21.2200	— 18	+ .2	+1.6	40 38 0.65	— 1 38.18	— 3	+ 24	— 3	22.65	+2	63.1
	III	X	21.8343	20.0823	+ 10	+1.4	— .2	40 37 7.00	— 44.27	+ 2	+ 19	— 1	22.93	+1	62.9
			16.3867	22.9130	— 15	+ .2	— .5	40 33 38.00	+ 2 44.79	+ 22	— 4	+ 5	23.02	+1	62.6
			21.6597	22.2307	+ 7	+ .6	+ .4	40 36 37.29	— 14.44	+ 12	+ 14	0	23.11	—2	59.4
			22.3490	22.3663	0	+1.2	— .4	40 36 22.46	+ 0.44	+ 10	+ 14	0	23.14	—3	
			29.6337	12.0000	+ 86	—2.1	—2.2	40 28 57.16	+ 7 25.59	+ 49	— 60	+14	22.78	—3	59.6
	I	II	20.3320	24.2683	+ 54	—1.4	—2.5	40 38 3.25	— 1 39.56	+ 1	— 54	— 3	23.13	—3	
			28.6713 ^{iv}	10.4980 ⁱⁱ	+ 3	— .8	+1.2	40 28 42.40	+ 7 39.01	+1.31	+ 3	+13	22.88	—4	
			9.5130 ⁱⁱ	30.1497 ^{iv}	0	+ .6	+1.4	40 27 40.21	+ 8 41.23	+1.36	+ 28	+15	23.23	—4	58.9
			28.3140 ^{iv}	12.0343 ⁱⁱ	— 3	+ .8	+ .1	40 29 30.50	+ 6 51.17	+1.25	+ 6	+12	23.10	—4	
			12.2887	27.0183	— 31	+ .2	0	40 42 35.60	— 6 11.95	— 28	+ 3	—11	23.29	—5	58.6
July 11	III	X	23.5473	20.4667	+ 18	— .9	—1.0	40 37 15.87	— 52.59	+ 7	— 26	— 2	23.07	—4	
			23.8270	16.0307	— 3	+ .7	— .4	40 39 40.53	— 3 16.90	— 13	+ 6	— 5	23.51	—5	
			33.1627 ^{iv}	4.0877 ⁱⁱ	— 73	—2.3	—1.7	40 24 7.73	+12 14.15	+1.58	— 57	+23	23.12	—5	57.7
			13.8533	27.1150	+ 33	+2.2	+2.2	40 41 57.39	— 5 35.02	— 26	+ 62	—10	22.63	+7	70.5
			10.7100 ⁱⁱ	30.1543 ^{iv}	0	+ .9	+ .3	40 28 10.17	+ 8 11.07	+1.36	+ 18	+16	22.94	+6	
	I	II	19.0660	21.0820	0	+ .7	+ .8	40 35 32.26	+ 50.91	+ 11	+ 21	+ 2	23.51	+6	
			12.3490 ⁱⁱ	26.8707 ^{iv}	+ 13	+1.3	— .1	40 30 14.49	+ 6 6.80	+1.23	+ 18	+10	22.80	+6	
			30.4780 ^{iv}	8.8593 ⁱⁱ	0	+ .5	+1.9	40 45 29.89	— 9 5.98	—1.22	+ 32	—21	22.80	+5	70.6
			22.0467	18.3390	+ 3	—2.1	—2.4	40 34 49.63	+ 1 33.64	+ 16	— 63	+ 3	22.83	+5	70.1
			15.8743	26.2830	+ 67	+ .4	0	40 31 59.39	+ 4 23.04	+ 31	+ 6	+ 8	22.88	+5	
	III	X	30.6780	10.0310	+ 44	+1.6	+1.1	40 45 4.84	— 8 41.55	— 44	+ 39	—16	23.08	+5	71.0
			29.2130	10.7777	0	+2.4	+ .9	40 44 8.63	— 7 45.58	— 37	+ 48	—14	23.02	+5	
			7.2340 ⁱⁱ	32.2860 ^{iv}	— 9	—1.2	— .1	40 46 56.99	—10 32.66	—1.35	— 20	—19	22.59	+4	70.6
			12.0373	28.5880	+ 33	+1.3	+ .7	40 43 19.85	— 6 56.81	— 30	+ 29	—15	22.88	+4	
			30.4047 ^{iv}	5.4917 ⁱⁱ	— 59	+1.6	+1.2	40 46 53.07	—10 29.03	—1.30	+ 38	—24	22.88	+3	70.4

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
July 16	X	1 R	27.6787	14.4277	+ 83	+ .4	0	40 41 57.86	- 5 34.85	- 26	+ 6	-10	40 36 22.71	+7	77.8
		2	31.8787 ^{iv}	12.4063 ⁱⁱ	- 7	-1.8	-1.5	40 28 10.61	+ 8 11.73	+1.36	- 47	+16	23.39	+7	
		3	22.2077	20.2197	+ 14	- .1	+ .1	40 35 32.82	+ 50.24	+ 11	0	+ 2	23.19	+7	
		4	28.1850 ^{iv}	13.6463 ⁱⁱ	- 30	-2.6	-2.8	40 30 15.11	+ 6 7.08	+1.23	- 76	+10	22.76	+7	
		5	10.5920 ⁱⁱ	32.2093 ^{iv}	+ 13	0	0	40 45 30.38	- 9 5.95	-1.22	0	-21	23.00	+6	77.8
July 17	X	6	19.9397	23.6220	+ 39	+ .3	+ .9	40 34 50.31	+ 1 33.09	+ 16	+ 16	+ 3	23.75	+6	
		7	26.7013	16.2867	+ 92	-2.4	-1.6	40 32 0.21	+ 4 23.24	+ 31	- 58	+ 8	23.26	+6	77.7
		8	11.0117	31.6497	+163	-1.0	-1.2	40 45 5.68	- 8 41.60	- 44	- 31	-16	23.17	+6	
		9	11.4950	29.9030	+ 74	- .5	- .7	40 44 9.51	- 7 45.06	- 37	- 17	-14	23.77	+5	76.0
		9 D	29.4583	11.0133	+ 27	-1.1	- .7	40 44 9.71	- 7 45.88	- 37	- 26	-14	23.06	+5	75.0
	XI	10	7.7450 ⁱⁱ	32.8463 ^{iv}	+ 7	- .4	+ .8	40 46 58.22	-10 33.94	-1.35	+ 4	-19	22.78	+5	74.4
		1	11.3107	27.8533	- 40	+ .7	+ .8	40 43 20.97	- 6 57.67	- 30	+ 21	-15	23.06	+4	73.4
		2	31.1647 ^{iv}	6.2357 ⁱⁱ	- 39	-1.1	-1.5	40 46 54.24	-10 29.47	-1.30	- 36	-24	22.87	+4	73.1
		3	32.5980 ^{iv}	7.9413 ⁱⁱ	+ 7	-2.7	-5.2	40 25 59.68	+10 22.71	+1.46	-1.08	+18	22.95	+4	
		4	32.4567 ^{iv}	8.0087 ⁱⁱ	+ 8	+ .7	+1.0	40 26 4.25	+10 17.44	+1.46	+ 24	+18	23.57	+4	
	I	5	34.2337 ^{iv}	1.8913 ⁱⁱ	-141	- .3	0	40 22 45.39	+13 36.43	+1.66	- 4	+25	23.69	+3	
		6	13.3687	24.6237	- 68	-1.5	-1.4	40 31 39.33	+ 4 44.07	+ 34	- 41	+10	23.43	+3	71.4
		7	21.1387	17.1987	- 20	0	+ .3	40 38 2.57	- 1 39.45	- 3	+ 4	- 3	23.10	+3	71.4
		8	19.0943	20.9577	0	+2.0	+3.6	40 37 8.97	- 47.06	+ 1	+ 77	- 1	22.68	+2	
		1	23.9377	17.4937	+ 27	-1.4	-1.3	40 33 40.02	+ 2 42.81	+ 21	- 38	+ 5	22.71	+2	71.2
	II	1 D	20.0883	19.4597	0	- .7	-2.1	40 36 39.17	- 15.88	+ 12	- 38	0	23.03	-2	70.4
		2	19.5030	19.5173	0	-5.2	-5.4	40 36 24.40	- 0.36	+ 10	-1.50	0	22.64	-2	
		3	10.8740	28.4550	- 35	- .4	-2.1	40 28 59.26	+ 7 23.92	+ 49	- 33	+14	23.48	-2	70.3
		4	21.4727	17.4160	- 15	+1.3	+ .1	40 38 5.21	- 1 42.41	0	+ 22	- 3	22.99	-2	
		5	11.1807 ⁱⁱ	29.2797 ^{iv}	- 2	+ .2	+ .9	40 28 44.54	+ 7 37.09	+1.30	+ 14	+13	23.20	-3	69.8
July 18	X	6	30.0727 ^{iv}	9.5100 ⁱⁱ	0	- .7	-1.7	40 27 42.34	+ 8 39.32	+1.35	- 32	+15	22.84	-3	70.0
		7	11.1977 ⁱⁱ	27.3733 ^{iv}	+ 19	+2.0	+1.0	40 29 32.60	+ 6 48.57	+1.25	+ 44	+12	22.98	-4	
		8	26.4617	11.6497	- 84	+1.3	+ .4	40 42 37.60	- 6 13.86	- 28	+ 25	-11	23.60	-4	69.6
		9	18.4757	20.6503	- 5	+ .3	- .8	40 37 17.65	- 54.91	+ 7	- 6	- 2	22.73	-4	
		1	16.3170	24.1957	+ 11	0	+1.4	40 39 42.49	- 3 19.00	- 13	+ 18	- 5	23.49	-4	
	X	2	3.6577 ⁱⁱ	32.6450 ^{iv}	- 99	0	- .4	40 24 9.61	+12 11.83	+1.58	- 5	+23	23.20	-4	69.4
		3	24.6450	13.9470	- 44	+ .4	0	40 40 53.38	- 4 30.07	- 19	+ 6	- 9	23.09	-4	
		1 D	13.3433	26.6150	- 4	+1.4	+2.2	40 41 58.10	- 5 35.15	- 26	+ 50	-10	23.09	+7	77.0
		2	10.0723 ⁱⁱ	29.5023 ^{iv}	0	+1.2	+ .6	40 28 10.84	+ 8 10.69	+1.36	+ 26	+16	23.31	+7	
		3	18.2310	20.2230	- 9	+ .1	+ .2	40 35 33.09	+ 50.28	+ 11	+ 4	+ 2	23.54	+7	
	X	4	13.5567 ⁱⁱ	28.0723 ^{iv}	- 29	-1.2	+1.1	40 30 15.41	+ 6 6.51	+1.23	- 4	+10	23.21	+7	
		5	30.9617 ^{iv}	9.3207 ⁱⁱ	0	+ .3	- .4	40 45 30.63	- 9 6.53	-1.22	0	-21	22.67	+6	76.9
		6	21.2037	17.5437	- 17	-2.1	-2.0	40 34 50.64	+ 1 32.39	+ 16	- 58	+ 3	22.64	+6	77.4
		7	14.8197	25.1927	0	+ .6	- .5	40 32 0.59	+ 4 21.96	+ 31	+ 3	+ 8	22.97	+6	75.6
		8	30.0613	9.3547	- 39	+ .8	+1.4	40 45 6.06	- 8 42.82	- 44	+ 30	-16	22.94	+6	75.1
	II	9	29.4443	10.9603	+ 19	+ .7	+ .4	40 44 9.91	- 7 46.84	- 37	+ 16	-14	22.72	+6	74.8
		3 R	29.0473	11.5020	+ 27	-1.9	-2.5	40 28 59.54	+ 7 23.18	+ 49	- 62	+14	22.73	-2	70.5
		4	18.8000	22.8893	+ 21	+ .8	+ .8	40 38 5.46	- 1 43.33	0	+ 22	- 3	22.32	-2	
		5	29.7623 ^{iv}	11.6830 ⁱⁱ	- 8	-1.2	0	40 28 44.81	+ 7 36.58	+1.30	- 18	+13	22.64	-3	
		6	10.2233 ⁱⁱ	30.7553 ^{iv}	0	+1.8	+ .5	40 27 42.60	+ 8 38.54	+1.35	+ 34	+15	22.98	-3	70.5
	III	7	28.0950 ^{iv}	11.9253 ⁱⁱ	0	- .4	- .8	40 29 32.86	+ 6 48.37	+1.25	- 16	+12	22.44	-4	
		8	13.5963	28.4110	+ 86	- .2	0	40 42 37.85	- 6 14.36	- 28	- 3	-11	23.07	-4	70.5
		9	22.6680	20.4983	+ 20	+1.6	+2.0	40 37 17.86	- 54.85	+ 7	+ 50	- 2	23.56	-3	
		1	23.2737	15.3780	- 30	+1.8	+ .8	40 39 42.74	- 3 19.33	- 13	+ 38	- 5	23.61	-4	69.8
		2	35.0683 ^{iv}	6.0940 ⁱⁱ	+ 31	0	- .5	40 24 9.84	+12 11.83	+1.58	- 6	+23	23.42	-4	70.3
July 19	X	3	13.1503	23.8647	- 96	+1.2	+ .6	40 40 53.60	- 4 30.35	- 19	+ 26	- 9	23.23	-4	
		5	22.9390	19.2897	+ 24	+1.8	+ .7	40 37 54.90	- 1 32.22	- 2	+ 37	- 3	23.00	-5	70.4
		9 R	10.9107	29.3633	+ 13	- .8	-1.4	40 44 10.13	- 7 46.05	- 37	- 30	-14	23.27	+6	71.3
		10	32.7253 ^{iv}	7.6237 ⁱⁱ	+ 4	+ .4	+ .2	40 46 58.68	-10 33.95	-1.35	+ 8	-19	23.27	+5	71.0
		XI 1	29.5917	13.0200	+127	+ .8	+2.2	40 43 21.40	- 6 58.84	- 30	+ 40	-15	22.51	+4	71.2

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections.				Latitude		Δ	Ther.
						A	B		Micrometer	δ	l	r				
July 19	XI	2 R	8.6400 ⁱⁱ	33.6043 ^{iv}	+ 33	+1.5	+1.7	40 46 54.68	-10 30.56	-1.30	+ 44	-24	40 36 23.02	+4		
		3	8.7527 ⁱⁱ	33.3073 ^{iv}	+ 28	+4.5	+3.5	40 26 0.21	+10 20.20	+1.46	+1.14	+18	23.19	+4		
		4	8.5790 ⁱⁱ	33.0183 ^{iv}	+ 21	-2.4	-1.7	40 26 4.78	+10 17.27	+1.46	- 59	+18	23.10	+4		
		5	2.2243 ⁱⁱ	34.5130 ^{iv}	-117	+1.7	+2.0	40 22 45.91	+13 35.16	+1.66	+ 52	+25	23.50	+3	70.6	
		6	26.9257	15.7300	+ 88	-2.5	- .5	40 31 39.85	+ 4 42.97	+ 34	- 45	+10	22.81	+3		
		7	18.6720	22.6233	+ 16	-1.7	- .6	40 38 3.14	- 1 39.83	- 3	- 34	- 3	22.91	+3	69.5	
	I	8	23.6360	21.7863	+ 30	+ .2	- .8	40 37 9.54	- 46.79	+ 1	- 7	- 1	22.68	+3	68.4	
		1	17.0553	23.4727	+ 11	+ .2	+ .3	40 33 40.61	+ 2 42.10	+ 21	+ 7	+ 5	23.04	+2	67.9	
	II	1 D	19.8870	19.2473	- 3	-2.6	-2.1	40 36 39.66	- 16.15	+ 12	- 68	0	22.95	-1		
		2	18.4487	18.4887	0	-1.1	-1.2	40 36 24.91	- 1.01	+ 10	- 32	0	23.68	-2	65.0	
		3	10.5123	28.0253	- 76	+ .5	- .3	40 28 59.81	+ 7 22.12	+ 49	+ 4	+14	22.60	-2		
		4	21.1007	17.0170	- 23	+ .7	- .9	40 38 5.71	- 1 43.08	0	0	- 3	22.60	-2	64.1	
		5	11.2143 ⁱⁱ	29.2880 ^{iv}	- 3	+ .1	- .1	40 28 45.09	+ 7 36.47	+1.30	0	+13	22.99	-3		
		6	30.8417 ^{iv}	10.2777 ⁱⁱ	0	-2.7	-2.2	40 27 42.88	+ 8 39.37	+1.35	- 70	+15	23.05	-3	64.4	
		7	12.6950 ⁱⁱ	28.8687 ^{iv}	- 18	+ .2	+ .2	40 29 33.14	+ 6 48.45	+1.25	+ 6	+12	23.02	-3	63.5	
	III	8	27.4110	12.5830	0	+1.7	+1.4	40 42 38.11	- 6 14.50	- 29	+ 44	-11	23.65	-3		
		9	18.1830	20.3647	- 9	-1.3	-2.2	40 37 18.09	- 55 08	+ 7	- 48	- 2	22.58	-3	61.9	
		1	16.4080	24.2830	+ 14	-2.1	-1.2	40 39 42.98	- 3 18.93	- 13	- 48	- 5	23.39	-4		
		2	3.8383 ⁱⁱ	32.8137 ^{iv}	- 88	+ .1	- .6	40 24 10.08	+12 11.59	+1.58	- 6	+23	23.42	-4	61.7	
		4	25.7973	14.5017	+ 9	- .7	-1.0	40 41 9.59	- 4 45.31	- 21	- 24	- 8	23.75	-5	61.2	
July 20	X	5	17.2027	20.8227	- 21	-1.4	-1.8	40 37 55.09	- 1 31.38	- 2	- 44	- 3	23.22	-4		<i>d</i>
		3 R	21.5847	19.5897	+ 6	- .5	-1.5	40 35 33.41	+ 50.40	+ 11	- 27	+ 2	23.67	+7	71.2	
		4	28.5353 ^{iv}	14.0330 ⁱⁱ	- 43	- .6	- .8	40 30 15.76	+ 6 6.16	+1.23	- 20	+10	23.05	+7		
		5	10.4283 ⁱⁱ	32.0523 ^{iv}	+ 12	-2.0	- .2	40 45 30.93	- 9 6.15	-1.22	- 34	-21	23.01	-6	71.2	
		6	19.4043	23.0377	+ 25	+1.0	+ .9	40 34 51.01	+ 1 31.57	+ 16	+ 27	+ 3	23.04	+6	70.4	
		7	25.6817	15.2903	+ 31	-2.1	-3.3	40 32 1.00	+ 4 22.51	+ 31	- 74	+ 8	23.16	+6		
		9	28.6180	10.1297	- 68	+ .5	- .2	40 44 10.36	- 7 46.76	- 37	+ 6	-14	23.15	+6	69.9	
		10	7.5440 ⁱⁱ	32.6557 ^{iv}	+ 3	- .9	- .6	40 46 58.93	-10 34.21	-1.35	- 22	-18	22.97	+6	70.0	
	XI	1	10.5540	27.1370	-112	+1.6	+ .4	40 43 21.64	- 6 58.53	- 30	+ 30	-15	22.96	+5	69.6	
		2	31.7517 ^{iv}	6.7900 ⁱⁱ	- 21	+ .2	+ .6	40 46 54.92	-10 30.36	-1.30	+ 10	-24	23.12	+4		
		3	32.3290 ^{iv}	7.7050 ⁱⁱ	0	-1.8	-2.6	40 26 0.49	+10 21.88	+1.46	- 61	+18	23.40	+4	68.9	
		4	32.2417 ^{iv}	7.8020 ⁱⁱ	0	- .2	- .5	40 26 5.06	+10 17.23	+1.46	- 10	+18	23.83	+4	68.1	
		5	33.5600 ^{iv}	1.2473 ⁱⁱ	-187	-1.6	- .1	40 22 46.17	+13 35.60	+1.66	- 26	+25	23.42	+4		
		6	13.1443	24.3267	- 83	+ .8	+1.0	40 31 40.14	+ 4 42.20	+ 34	+ 25	+10	23.03	+3	68.1	
		7	21.7900	17.7950	- 5	+1.3	+1.0	40 38 3.44	- 1 40.88	- 4	+ 32	- 3	22.81	+3		
July 23	II	8	18.2373	20.0717	- 12	-1.7	-2.2	40 37 9.86	- 46.30	+ 2	- 54	- 1	23.03	+3	67.9	
		9	22.3177	15.8837	- 36	- .6	-1.3	40 33 40.93	+ 2 42.40	+ 21	- 26	+ 5	23.33	+2	66.6	
		1 R	20.3730	21.0930	+ 3	+3.2	+1.5	40 36 40.82	- 18.19	+ 11	+ 68	0	23.42	-1	62.9	
		2	20.9173	20.8097	0	+2.2	+ .1	40 36 26.10	- 2.72	+ 10	+ 36	0	23.84	-1	63.0	
		3	29.3800	11.9387	+ 68	+2.3	+1.2	40 29 1.08	+ 7 20.68	+ 49	+ 51	+14	22.90	-2		
		4	19.1707	23.2750	+ 30	-2.0	- .4	40 38 6.90	- 1 43.74	0	- 36	- 3	22.77	-2		
		5	29.3737 ^{iv}	11.3717 ⁱⁱ	- 5	+ .6	+ .3	40 28 46.37	+ 7 34.66	+1.26	+ 14	+13	22.56	-2	60.9	
		6	10.1530 ⁱⁱ	30.6240 ^{iv}	0	+ .6	- .1	40 27 44.15	+ 8 37.03	+1.31	+ 8	+15	22.72	-3		
		7	28.6303 ^{iv}	12.5073 ⁱⁱ	- 15	-1.0	-1.5	40 29 34.38	+ 6 47.17	+1.21	- 34	+12	22.54	-3	61.1	
		8	12.9097	27.7463	+ 28	-1.0	-1.0	40 42 39.29	- 6 14.80	- 28	- 28	-11	23.82	-3		
		9	22.4530	20.2540	+ 18	-1.5	- .8	40 37 19.13	- 55.58	+ 7	- 33	- 2	23.27	-3	60.4	
	III	1	24.3160	16.3743	+ 16	+ .7	+ .4	40 39 44.12	- 3 20.63	- 13	+ 16	- 5	23.47	-4	59.9	
		2	34.3480 ^{iv}	5.4237 ⁱⁱ	- 8	-2.5	- .7	40 24 11.16	+12 10.52	+1.54	- 48	+23	22.97	-4		
		3	13.6327	24.3943	- 63	-1.8	-1.6	40 40 54.87	- 4 31.65	- 19	- 48	- 9	22.46	-4		
		4	13.7677	25.1257	- 38	- .7	+ .5	40 41 10.60	- 4 46.77	- 21	- 4	- 8	23.50	-4	59.2	
		5	24.3560	20.6750	+ 56	+1.8	+2.5	40 37 55.99	- 1 33.11	- 2	+ 60	- 3	23.43	-4		
		6	15.5243	29.3150	+197	- .8	-1.0	40 42 13.11	- 5 48.81	- 20	- 25	-14	23.71	-4	58.8	
July 27	XI	7 R	23.6747	18.0777	+ 31	+ .6	- .1	40 38 44.67	- 2 21.44	- 7	+ 8	- 4	23.20	-5	58.1	
		1	29.9867	13.3900	+167	- .6	- .1	40 43 23.04	- 6 59.59	- 38	- 11	-15	22.81	+5	67.6	
		2	9.2897 ⁱⁱ	34.3117 ^{iv}	+ 53	+ .8	0	40 46 56.41	-10 32.09	-1.33	+ 12	-24	22.87	+5	66.7	

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
July 27	XI 3 R		8.0207 ^{II}	32.5150 ^{IV}	+ 8	+2.4	+1.4	40 26 2.31	+10 18.65	+1.51	+ 55	+18	40 36 23.20	+5	
			8.1707 ^{II}	32.5137 ^{IV}	+ 10	— .1	—1.0	40 26 6.88	+10 14.83	+1.50	— 14	+18	23.25	+5	66.3d
			2.1437 ^{II}	34.3507 ^{IV}	—126	+1.5	— .6	40 22 48.02	+13 33.11	+1.73	+ 16	+25	23.27	+5	65.8
			25.7623	14.6477	+ 14	—2.0	—1.5	40 31 41.98	+ 4 40.75	+ 39	— 50	+10	22.72	+4	64.2
			17.9590	22.0057	0	—1.2	—2.0	40 38 5.47	— 1 42.21	— 6	— 44	— 3	22.73	+4	
	I		22.1033	20.1620	+ 12	—1.0	—1.5	40 37 11.93	— 49.06	+ 1	— 34	— 1	22.53	+4	64.0
			17.7010	24.0183	+ 30	— .9	—1.2	40 33 43.07	+ 2 39.63	+ 24	— 30	+ 5	22.69	+3	63.4
			13.1850	27.1493	+ 11	0	0	40 42 17.55	— 5 53.97	— 34	0	—10	23.14	+2	62.6
			17.6943	23.2100	+ 16	— .2	— .4	40 34 3.72	+ 2 19.35	+ 22	— 8	+ 3	23.24	+3	62.1
			23.7980	19.9707	+ 43	+ .2	— .4	40 34 46.26	+ 1 36.78	+ 17	— 2	+ 3	23.22	+2	
			23.5947	18.5147	+ 32	+ .4	+ .1	40 34 14.59	+ 2 8.88	+ 20	+ 8	+ 3	23.28	+2	62.5
			21.1357	20.2353	+ 3	— .1	+ .5	40 35 59.53	+ 22.75	+ 12	+ 5	+ 1	22.46	+1	
			11.6617	30.6997	+133	— .5	— .4	40 28 20.96	+ 8 1.16	+ 61	— 13	+15	22.75	+1	
			8.4913 ^{II}	32.5283 ^{IV}	+ 12	+ .8	—1.2	40 26 14.82	+10 7.12	+1.49	— 3	+17	23.57	+1	62.3
			14.5127	26.7410	+ 44	+1.1	— .6	40 31 14.04	+ 5 8.95	+ 41	+ 10	+ 8	23.58	+1	62.4
July 29	XI 1 D		28.1567	17.1467	+171	— .8	—2.0	40 41 2.63	— 4 38.50	— 18	— 38	—11	23.46	0	61.0
			11.9133	28.5593	+ 24	+ .7	+ .7	40 43 23.34	— 7 0.44	— 37	+ 20	—15	22.58	+6	75.5
			31.5050 ^{IV}	6.4507 ^{II}	— 31	+1.6	+1.6	40 46 56.71	—10 32.66	—1.34	+ 46	—24	22.93	+5	75.5
			32.5757 ^{IV}	8.0780 ^{II}	+ 11	—1.0	— .2	40 26 2.70	+10 18.70	+1.50	— 18	+18	22.90	+5	
			32.5053 ^{IV}	8.1603 ^{II}	+ 10	— .6	— .3	40 26 7.28	+10 14.84	+1.49	— 14	+18	23.65	+5	
	I		33.5730 ^{IV}	1.3340 ^{II}	—181	—2.3	—1.3	40 22 48.43	+13 33.72	+1.73	— 52	+25	23.61	+5	74.6
			14.0610	25.1577	— 26	+ .2	— .1	40 31 42.40	+ 4 40.17	+ 39	+ 2	+10	23.08	+4	
			22.5230	18.4567	+ 14	+ .3	— .3	40 38 5.93	— 1 42.73	— 6	0	— 3	23.11	+4	72.9
			19.9770	21.9330	+ 11	— .4	—2.6	40 37 12.41	— 49.43	+ 1	— 39	— 1	22.59	+4	72.8d
			23.4787	17.1610	+ 13	—1.2	+ .5	40 33 43.56	+ 2 39.59	+ 24	— 12	+ 5	23.32	+4	
			27.6990	13.6757	+ 56	—1.9	—3.1	40 42 18.05	— 5 54.30	— 34	— 69	—10	22.62	+3	71.1
			24.3733	18.8737	+ 56	— .8	—1.0	40 34 4.25	+ 2 19.03	+ 22	— 25	+ 3	23.28	+3	71.5
			18.9710	22.7753	+ 21	+ .1	— .2	40 34 46.80	+ 1 36.13	+ 17	— 1	+ 3	23.12	+3	71.1
			18.1367	23.1967	+ 20	+1.6	+1.3	40 34 15.15	+ 2 7.83	+ 20	+ 42	+ 3	23.63	+2	71.5
			19.2763	20.2073	0	— .7	—1.8	40 36 0.03	+ 23.52	+ 12	— 34	+ 1	23.34	+2	
July 30	XI 1 R		29.6537	10.6073	+ 15	—1.5	—2.4	40 28 21.49	+ 8 1.04	+ 12	— 54	+15	22.26	+1	
			33.4680 ^{IV}	9.4613 ^{II}	+ 35	—1.1	— .5	40 26 15.40	+10 6.37	+1.49	— 24	+17	23.19	+1	
			27.1577	14.9573	+ 77	— .3	— .6	40 31 14.45	+ 5 8.31	+ 41	— 12	+ 8	23.13	+1	
			14.2860	25.3617	— 13	—1.2	— .2	40 41 3.12	— 4 39.68	— 19	— 21	—11	22.93	0	71.0
			29.1750	12.5573	+ 84	—1.0	— .9	40 43 23.47	— 6 59.89	+ 5	— 27	—15	23.21	+6	71.0
	I		8.6480 ^{II}	33.6710 ^{IV}	+ 35	+ .2	— .8	40 46 56.87	—10 32.04	—1.34	— 7	—24	23.18	+5	70.6
			8.5100 ^{II}	32.9927 ^{IV}	+ 20	+1.6	+2.3	40 26 2.91	+10 18.37	+1.50	+ 54	+18	23.50	+6	70.2
			8.1683 ^{II}	32.5057 ^{IV}	+ 10	+ .9	— .2	40 26 7.48	+10 14.67	+1.49	+ 12	+18	23.94	+5	
			1.7590 ^{II}	33.9643 ^{IV}	—154	— .4	—1.4	40 22 48.63	+13 32.96	+1.73	— 24	+25	23.33	+5	d
			26.1783	15.1010	+ 42	+ .8	— .6	40 31 42.60	+ 4 39.87	+ 39	+ 5	+10	23.01	+5	70.6
			19.5633	23.6267	+ 37	—1.4	— .9	40 38 6.16	— 1 42.71	— 6	— 33	— 3	23.03	+4	69.8d
			20.8550	18.8763	0	+ .1	— .3	40 37 12.65	— 49.97	0	— 2	— 1	22.65	+4	69.4
			18.1877	24.4820	+ 51	— .5	—1.1	40 33 43.81	+ 2 39.09	+ 24	— 22	+ 5	22.97	+4	
			18.1167	23.5973	+ 28	+ .7	— .1	40 34 4.51	+ 2 18.48	+ 22	+ 10	+ 3	23.34	+3	69.3
			23.7523	19.9503	+ 42	—1.5	—1.7	40 34 47.06	+ 1 36.12	+ 17	— 44	+ 3	22.94	+3	69.2
Aug. 2	III 1 D		22.5670	17.5067	0	—1.3	—1.2	40 34 15.41	+ 2 7.80	+ 20	— 36	+ 3	23.08	+2	68.4
			22.4543	21.5477	+ 13	— .8	— .4	40 36 0.27	+ 22.93	+ 12	— 18	+ 1	23.15	+2	
			11.1753	30.1920	+ 75	—1.9	—1.1	40 28 21.76	+ 8 0.46	+ 61	— 44	+15	22.54	+1	
			9.1843 ^{II}	33.1753 ^{IV}	+ 28	+ .8	0	40 26 15.68	+10 5.97	+1.49	+ 12	+17	23.43	+1	69.0
			14.7110	26.8687	+ 57	+1.9	+ .5	40 31 14.91	+ 5 7.18	+ 41	+ 36	+ 8	22.94	+1	
	5		28.0510	17.0187	+165	+ .3	— .8	40 41 3.35	— 4 39.04	— 19	— 6	—11	23.95	0	68.4
			16.5610	24.6060	+ 29	— .4	— .9	40 39 47.02	— 3 23.26	— 17	— 18	— 5	23.36	—2	64.0
			5.4570 ^{II}	34.2923 ^{IV}	— 6	—1.2	—2.9	40 24 13.97	+12 8.26	+1.63	— 56	+23	23.53	—3	63.9
			26.3873	14.9267	+ 44	—1.5	—2.5	40 41 13.31	— 4 49.56	— 27	— 55	— 8	22.85	—3	63.6a
			18.4930	22.2560	+ 10	—1.6	—1.1	40 37 53.45	— 1 35.07	— 4	— 39	— 3	22.92	—3	63.6

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude		Δ	Ther.
						A	B		Micrometer			i	r			
Aug. 2	III 6	D	26.5543	12.6377	-34	+1.6	+1.3	40 42 15.31	-5	51.89	-27	+42	-14	23.93	-3	
	7		17.8777	23.5437	+24	-1.8	-1.2	40 38 47.05	-2	23.16	-10	-44	-4	23.31	-4	68.9
	8		25.8680	15.4217	+39	-.2	-.6	40 40 47.75	-4	23.93	-22	-10	-9	23.41	-4	
Aug. 5	XI 10		9.9197 ^{II}	31.6797 ^{IV}	+9	-.4	-.2	40 27 12.82	+9	9.59	+1.41	-8	+15	23.89	-4	68.0
	XI 1	D	11.4640	28.1570	-17	+2.0	+1.5	40 43 24.55	-7	1.53	-38	+50	-15	22.99	+6	77.2
	2		31.3603 ^{IV}	6.2827 ^{II}	-35	-.7	-.6	40 46 58.03	-10	33.22	-1.35	-18	-24	23.04	+6	76.7
	3		32.4107 ^{IV}	7.9827 ^{II}	+7	-.2	+.3	40 26 4.32	+10	16.93	+1.50	+1	+18	22.94	+6	
	4		32.1407 ^{IV}	7.8817 ^{II}	0	+1.2	+1.2	40 26 8.90	+10	12.65	+1.49	+34	+18	23.56	+6	
	5		33.7320 ^{IV}	1.5953 ^{II}	-170	+1.2	+.9	40 22 50.06	+13	31.15	+1.73	+30	+25	23.49	+6	76.6
	6		13.6207	24.6450	-56	+1.1	+.6	40 31 44.04	+4	38.27	+39	+24	+10	23.04	+5	76.4
	7		22.3360	18.2000	+8	-.8	-1.4	40 38 7.74	-1	44.47	-6	-30	-3	22.88	+5	76.1
	8		19.1957	21.2237	0	+.2	+.1	40 37 14.28	-	51.22	0	+4	-1	23.09	+5	75.6
	I 1		23.0753	16.8753	-0	+.4	+1.1	40 33 45.49	+2	36.58	+24	+20	+5	22.56	+5	
	2		26.4900	12.3757	-48	+.7	-.5	40 42 20.01	-5	56.32	-34	+4	-10	23.29	+4	74.4
	4		23.0873	17.6680	+13	-2.0	-2.2	40 34 6.27	+2	16.89	+22	-59	+3	22.82	+4	
	5		17.3923	22.3500	-3	+.6	0	40 34 17.24	+2	5.19	+20	+10	+3	22.76	+3	72.5
	6		19.1853	20.0000	-3	+1.0	+.6	40 36 1.93	+20.57	+11	+23	+1		22.85	+3	72.2
	7		29.5510	10.5887	+6	-.3	+.1	40 28 23.55	+7	58.90	+61	-3	+15	23.18	+2	
	8		32.0613 ^{IV}	8.1520 ^{II}	+3	-1.0	+.1	40 26 17.57	+10	3.82	+1.48	-14	+17	22.90	+2	
	9		26.7967	14.7027	+54	0	-.1	40 31 16.82	+5	5.56	+41	-2	+8	22.85	+2	71.9
	III 1	R	24.5013	16.4200	+21	-1.0	-.7	40 39 47.95	-3	24.14	-17	-24	-5	23.35	-2	69.9
	2		35.0467 ^{IV}	6.2680 ^{II}	+32	-1.5	-1.9	40 24 14.89	+12	6.89	+1.63	-47	+23	23.17	-2	69.9
	3		16.4270	27.2917	+120	-1.7	-.4	40 40 58.45	-4	34.69	-24	-32	-9	23.11	-2	70.0
	4		14.7147	26.2340	+31	+.7	+.8	40 41 14.16	-4	51.00	-27	+21	-8	23.02	-3	
	6		13.6893	27.6243	+56	+.3	+.1	40 42 15.98	-5	52.08	-27	+6	-14	23.55	-3	69.6
	7		24.4313	18.7233	+53	+.9	-.4	40 38 47.75	-2	24.29	-10	+9	-4	23.41	-4	69.4
	8		16.4057	26.8343	+100	-1.9	-3.0	40 40 48.41	-4	23.63	-22	-68	-9	23.79	-4	69.1
Aug. 6	9		27.6457	15.9653	+128	-.7	-.5	40 31 27.98	+4	55.82	+43	-18	+11	23.66	-3	
	10		31.4237 ^{IV}	9.7290 ^{II}	+5	+2.4	+3.0	40 27 13.45	+9	7.91	+1.41	+75	+15	23.67	-4	69.5
	III 1	D	16.5560	24.6643	+29	+.7	0	40 39 48.29	-3	24.86	-17	+11	-5	23.32	-2	62.1
	2		5.3777 ^{II}	34.1657 ^{IV}	-10	-1.4	-2.7	40 24 15.19	+12	7.06	+1.63	-56	+23	23.55	-2	
	3		24.8723	13.9550	-36	+1.3	+.6	40 40 58.27	-4	35.65	-24	+28	-9	22.57	-2	62.4
	4		25.3673	13.8560	-26	+.8	-2.2	40 41 14.48	-4	50.67	-27	-16	-8	23.30	-3	
	5		18.1613	21.9530	0	-1.6	-2.0	40 37 59.51	-1	35.77	-4	-50	-3	23.17	-3	61.8
	6		25.2737	11.3160	-141	+.2	-.9	40 42 16.25	-5	52.17	-27	-8	-14	23.59	-3	61.6
	7		17.9700	23.6877	+31	-1.4	+.3	40 38 48.05	-2	24.49	-10	-18	-4	23.24	-4	61.8
	8		24.0440	13.5720	-75	-.7	-1.4	40 40 48.63	-4	24.30	-22	-29	-9	23.73	-3	
	9		13.0977	24.7897	-72	-1.6	-1.6	40 31 28.21	+4	55.11	+43	-46	+11	23.40	-3	
Aug. 7	10		9.5247 ^{II}	31.2427 ^{IV}	+2	-.5	-.5	40 27 13.69	+9	8.53	+1.41	-14	+15	23.64	-4	60.6
	XI 1	R	30.3157	13.6410	+194	+.5	+.6	40 43 24.88	-7	1.61	-38	+16	-15	22.90	+6	71.3
	2		8.8623 ^{II}	33.9490 ^{IV}	+42	+.2	-.4	40 46 58.38	-10	33.67	-1.35	-2	-24	23.10	+6	69.8
	III 1	R	24.4190	16.3060	+17	-1.2	-.3	40 39 48.64	-3	24.94	-17	-22	-5	23.26	-2	65.6
	2		34.9620 ^{IV}	6.2383 ^{II}	+31	-.2	-.5	40 24 15.52	+12	5.52	+1.63	-10	+23	22.80	-2	
	3		14.2487	25.1440	-22	-.9	-.6	40 40 59.09	-4	35.12	-24	-22	-9	23.42	-2	
	4		15.4563	26.9807	+84	-1.4	-.7	40 41 14.81	-4	51.27	-27	-30	-8	22.89	-3	65.9a
	5		23.6463	19.8433	+39	+1.0	+.6	40 37 59.80	-1	36.14	-4	+23	-3	23.82	-3	65.5
	6		14.6823	28.6247	+136	-.4	-1.5	40 42 16.51	-5	52.46	-27	-25	-14	23.39	-3	65.4
	7		24.5287	18.7793	+60	+1.8	+.9	40 38 48.34	-2	25.36	-10	+40	-4	23.24	-3	65.2
	8		17.1127	27.5743	+147	-.9	-.9	40 40 48.89	-4	24.59	-22	-26	-9	23.73	-3	65.1
	9		27.4977	15.8487	+114	-1.3	-1.0	40 31 28.45	+4	54.49	+43	-32	+11	23.16	-3	
Aug. 8	10		31.6247 ^{IV}	9.9330 ^{II}	+8	+.8	-.3	40 27 13.95	+9	7.86	+1.41	+8	+15	23.45	-4	65.1
	XI 1	R	30.7933	14.1450	+243	-.1	-.6	40 43 25.11	-7	1.06	-37	-9	-15	23.44	+7	72.9
	2		9.5110 ^{II}	34.5940 ^{IV}	+61	-.5	-.6	40 46 58.56	-10	33.62	-1.35	-16	-24	23.19	+6	72.6
	3		8.1010 ^{II}	32.4773 ^{IV}	+9	+1.8	+1.6	40 26 4.99	+10	15.64	+1.50	+48	+18	22.79	+7	
	4		9.0567 ^{II}	33.2963 ^{IV}	+30	-.1	-.1	40 26 9.57	+10	12.24	+1.49	-3	+18	23.45	+6	

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections.				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Aug. 8	XI 5 R		2.8063 ^{II}	34.9377 ^{IV}	-82	-1.2	-1.6	40 22 50.75	+13 31.27	+1.73	-39	+25	40 36 23.61	+6	72.6
			26.6167	15.6267	+72	-1.0	-.2	40 31 44.75	+4 37.74	+38	-18	+10	22.79	+6	
			17.7910	21.9467	-4	-.9	-.2	40 38 8.53	-1 44.94	-6	-16	-3	23.34	+8	72.1
			21.3000	19.2400	+3	-.3	-.9	40 37 15.10	-52.03	0	-16	-1	22.90	+5	
	I 1		17.3513	23.5473	+17	-.3	-.3	40 33 46.36	+2 36.52	+24	-8	+5	23.09	+5	71.9
			13.0433	27.1773	+10	-1.8	-1.5	40 42 20.89	-5 56.98	-34	-47	-10	23.00	+5	71.1
			16.4687	21.8540	-27	+5	-.7	40 34 7.18	+2 15.93	+21	-1	+3	23.34	+4	71.1
			23.1763	19.4793	+29	-.2	-1.0	40 34 49.81	+1 33.44	+17	-16	+3	23.29	+4	
			23.5447	18.6007	+33	-1.1	-.2	40 34 18.22	+2 4.96	+20	-20	+3	23.21	+4	70.6
			22.4283	21.6233	+11	-.5	+4	40 36 2.83	+20.36	+11	-3	+1	23.28	+3	
			12.0313	30.9313	+165	-.8	-.8	40 28 24.51	+7 57.74	+61	-22	+15	22.79	+3	
			8.7127 ^{II}	32.6060 ^{IV}	+18	+3	-.1	40 26 18.62	+10 3.47	+1.48	+3	+17	23.77	+3	
			15.1763	27.2170	+84	+4	+5	40 31 17.86	+5 4.30	+40	+12	+8	22.76	+2	70.4
			27.9623	16.8037	+156	+3	-1.0	40 41 5.84	-4 42.21	-19	-8	-11	23.25	+1	70.6
	III 1 D		16.3133	24.4560	+20	+1	0	40 39 48.97	-3 25.70	-17	+2	-5	23.07	-2	67.6
			5.2177 ^{II}	33.9693 ^{IV}	-22	+8	-.9	40 24 15.87	+12 6.09	+1.63	+1	+23	23.83	-2	
			24.9210	13.9800	-35	-.1	-.4	40 40 59.42	-4 36.24	-24	-6	-9	22.79	-2	67.6
			26.1847	14.6630	+29	+4	-1.0	40 41 15.14	-4 51.06	-27	-6	-8	23.67	-2	a
			18.1897	22.0260	0	0	-.2	40 38 0.11	-1 36.88	-4	-2	-3	23.14	-3	67.1
			26.6877	12.7113	-24	-.6	-1.0	40 42 16.79	-5 52.92	-27	-22	-14	23.24	-3	66.9
			18.4830	24.2207	+48	-1.1	-1.7	40 38 48.64	-2 25.03	-10	-38	-4	23.09	-3	
			25.2720	14.7677	0	-.8	-2.4	40 40 49.16	-4 25.30	-23	-43	-9	23.12	-3	66.4
			13.9823	25.6340	-10	-1.6	-1.4	40 31 28.70	+4 54.24	+43	-43	+11	23.05	-3	
			8.6403 ^{II}	30.3320 ^{IV}	-5	-.8	-.3	40 27 14.21	+9 7.82	+1.41	-16	+15	23.43	-4	66.4
Aug. 9	XI 1 D		10.7347	27.4667	-90	+2.2	+2.3	40 43 25.15	-7 2.32	-38	+64	-15	22.94	+7	80.4
			30.8187 ^{IV}	5.6843 ^{II}	-52	+2.0	+7	40 46 58.70	-10 34.61	-1.35	+40	-24	22.90	+6	79.9
			34.0090 ^{IV}	9.6100 ^{II}	+45	-.9	-.4	40 26 5.17	+10 16.28	+1.50	-19	+18	22.94	+7	
			32.7307 ^{IV}	8.4927 ^{II}	+15	-.5	+1.1	40 26 9.77	+10 12.13	+1.49	+6	+18	23.63	+6	
			33.1857 ^{IV}	1.0607 ^{II}	-204	-.5	-1.1	40 22 50.95	+13 30.75	+1.73	-22	+25	23.46	+6	79.0
			15.1957	26.1707	+44	+1	-.1	40 31 44.94	+4 37.27	+38	0	+10	22.69	+6	
	I 1		22.8833	18.6937	+20	+3	+3	40 38 8.75	-1 45.85	-6	+8	-3	22.89	+8	78.8
			19.1467	21.2113	0	0	-.8	40 37 15.33	-52.14	0	-10	-1	23.08	+5	77.9
			24.1800	18.0070	+41	-.4	+5	40 33 46.61	+2 35.99	+24	0	+5	22.89	+5	77.5
			27.5303	13.3793	+40	-.3	-1.2	40 42 21.15	-5 57.46	-34	-20	-10	23.05	+5	
			23.5290	18.1490	+27	-.9	-1.3	40 34 7.46	+2 15.94	+21	-30	+3	23.34	+4	76.9
			18.2177	21.9057	0	-.1	-.6	40 34 50.09	+1 33.14	+17	-9	+3	23.34	+4	
			18.1157	23.0477	+17	+2	-.2	40 34 18.51	+2 4.59	+20	0	+3	23.33	+4	75.9
			19.2183	19.9983	-3	+1	+8	40 36 3.11	+19.69	+11	+12	+1	23.04	+3	
			30.2430	11.3543	+89	-1.6	-3.4	40 28 24.81	+7 57.23	+61	-68	+15	22.12	+3	
			32.5127 ^{IV}	8.6520 ^{II}	+14	+3	+1	40 26 18.91	+10 2.60	+1.48	+6	+17	23.22	+3	
			26.7673	14.7080	+53	-1.0	-1.0	40 31 18.19	+5 4.68	+41	-28	+8	23.08	+2	
			13.7227	24.9413	-45	+6	+8	40 41 6.12	-4 43.19	-19	+20	-11	22.83	+2	75.2
			24.8070	16.6687	+35	-1.3	-.8	40 39 49.32	-3 25.62	-17	-30	-5	23.18	-2	69.4
			34.1380 ^{IV}	5.4377 ^{II}	-12	-.1	+5	40 24 16.10	+12 4.80	+1.63	+5	+23	22.81	-2	
	III 1 R		15.8340	26.7597	+84	-.6	+1	40 40 59.74	-4 36.14	-24	-8	-9	23.19	-2	70.5
			14.4440	25.9870	+13	-1.4	-.7	40 41 15.46	-4 51.56	-27	-30	-8	23.25	-2	69.9
			24.2580	20.4380	+54	-.1	-.4	40 38 0.40	-1 36.61	-4	-6	-3	23.66	-3	69.4
			14.4603	28.4113	+119	-.8	-.6	40 42 17.06	-5 52.64	-27	-20	-13	23.82	-2	
			24.0773	18.3233	+41	-.3	-.5	40 38 48.93	-2 25.42	-10	-11	-4	23.26	-3	69.1
			16.7143	27.1973	+122	-1.0	-.4	40 40 49.43	-4 25.06	-23	-20	-9	23.85	-3	
Aug. 10	III 1 D		28.0047	16.3703	+149	-2.4	-2.3	40 31 28.96	+4 54.21	+43	-66	+11	23.05	-3	a
			31.3503 ^{IV}	9.6780 ^{II}	+6	-.6	-1.2	40 27 14.48	+9 7.35	+1.41	-25	+15	23.14	-4	68.2
			15.7817	23.9450	-6	+3	0	40 39 49.64	-3 26.16	-17	+4	-5	23.30	-1	68.5
			5.3010 ^{II}	34.0187 ^{IV}	-19	-2.1	-2.4	40 24 16.51	+12 5.24	+1.63	-63	+23	22.98	-2	
			23.5537	12.5730	-125	-1.6	-1.4	40 41 0.05	-4 37.01	-24	-43	-9	22.28	-2	

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude		Δ	Ther.
						A	B		Micrometer	δ	l	r				
Aug. 10	III 4 D		25.4128	13.8623	-26	+ .5	-.2	40 41 15.77	-4 51.63	-27	+	6 -8	40 36 23.85	-2	68.6	
			17.6370	21.4950	-12	-.6	-1.8	40 37 0.69	-1 37.40	-4	-	32 -3	22.90	-2		
			26.0820	12.0740	-77	+.6	0	40 42 17.32	-5 53.58	-27	+	10 -13	23.44	-2	67.3	
			16.9730	22.7577	-4	-.3	-.2	40 38 49.22	-2 26.09	-11	-	7 -4	22.91	-3	67.4	
			25.0627	14.5333	-15	+.4	+1.7	40 40 49.68	-4 25.89	-22	+	28 -9	23.76	-3	66.4	
Sept. 2	XI 1	9	13.1547	24.7840	-71	-.3	-.2	40 31 29.20	+4 53.52	+43	-	7 +11	23.19	-3		
		10	9.0990 ^{II}	30.7503 ^{IV}	0	+.5	+.3	40 27 14.74	+9 6.82	+1.41	+	12 +15	23.24	-4	66.7	
		1	27.6593	10.8663	-74	+.7	+1.1	40 43 27.46	-7 3.96	-47	+	25 -15	23.13	+8	63.6	
		2	7.8240 ^{II}	32.9920 ^{IV}	+14	-1.6	-2.0	40 47 1.43	-10 35.70	-1.29	-	50 -24	23.70	+8	62.3	
		3	8.6353 ^{II}	32.9180 ^{IV}	+19	-.8	-.7	40 26 8.74	+10 13.36	+1.43	-	22 +18	23.49	+9	c	
		4	8.8027 ^{II}	32.9103 ^{IV}	+21	-3.1	-1.8	40 26 13.42	+10 8.94	+1.42	-	71 +18	23.25	+8		
		5	2.7920 ^{II}	34.7710 ^{IV}	-86	-2.0	-2.2	40 22 54.76	+13 27.48	+1.70	-	59 +25	23.60	+8	60.8	
		6	26.2943	15.4443	+55	-2.5	-2.3	40 31 48.99	+4 34.18	+44	-	68 +10	23.03	+8	60.4	
	I 1	7	18.3147	22.6417	+14	-1.9	-1.7	40 38 13.26	-1 49.32	-8	-	51 -3	23.32	+8		
		8	21.6213	19.3617	+6	-.4	-.6	40 37 20.18	-57.08	-2	-	14 -1	22.93	+8	59.7	
		2	16.9283	22.9300	-4	-1.2	-1.7	40 33 51.65	+2 31.57	+26	-	40 +5	23.13	+8	59.4	
		3	14.2320	28.5640	+118	-2.1	-2.3	40 42 26.40	-6 2.28	-42	-	62 -10	22.98	+8	59.1	
		4	18.3327	23.5033	+28	-2.4	-3.5	40 34 13.03	+2 10.67	+23	-	82 +3	23.14	+7		
		5	23.7690	20.8000	+41	-2.8	-3.2	40 34 55.91	+1 27.72	+18	-	84 +3	23.00	+7	57.4	
		6	23.3483	18.6450	+28	-.7	-1.8	40 34 24.56	+1 58.86	+22	-	34 +3	23.33	+7		
		7	23.0243	22.4393	+10	-2.0	-.3	40 36 8.65	+14.80	+11	-	35 0	23.21	+6	56.2	
	IV 2 R	8	11.9937	30.6513	+147	-1.6	-1.2	40 28 30.88	+7 51.61	+70	-	40 +15	22.94	+6		
		9	9.2293 ^{II}	32.8500 ^{IV}	+22	-.5	-1.5	40 26 25.45	+9 56.65	+1.41	-	27 +17	23.41	+6	56.6	
		10	14.4137	26.2100	+19	+.1	-.8	40 31 24.89	+4 57.99	+46	-	8 +8	23.34	+6		
		1	26.5763	15.1940	+61	-1.1	-1.6	40 41 11.80	-4 47.64	-25	-	38 -11	23.42	+4	55.5	
		2	26.8983	15.5523	+80	+.6	-.5	40 41 10.67	-4 46.79	-32	+	3 -8	23.51	-2	50.4c	
		3	11.4077 ^{II}	30.9203 ^{IV}	-5	-1.6	-1.2	40 44 37.17	-8 12.85	-1.12	-	40 -17	22.63	-2	50.6	
		4	11.5263 ^{II}	30.0657 ^{IV}	-7	-1.4	+2.4	40 44 12.11	-7 48.26	-1.11	+	9 -14	22.69	-2		
		5	19.4910	23.6483	+38	+.6	0	40 34 37.54	+1 45.11	+19	+	10 +3	22.97	+3	50.4	
	Sept. 3	6	23.9867	16.8100	+16	+2.6	+1.4	40 39 23.82	-3 1.31	-19	+	58 -5	22.85	-3	50.8	
		7	33.6890 ^{IV}	8.2567 ^{II}	+32	-.2	+.6	40 25 38.61	+10 42.46	+1.51	+	4 +25	22.87	-2		
		8	28.1260	15.6943	+140	+2.6	+1.0	40 41 37.37	-5 14.36	-34	+	53 -10	23.10	-3	50.0	
		9	15.1400	23.0733	+123	+.9	+2.3	40 30 56.13	+5 26.99	+50	+	44 +10	24.16	-3		
		10	10.3690 ^{II}	31.8540 ^{IV}	+10	+1.8	+.7	40 27 18.80	+9 2.71	+1.34	+	37 +17	23.39	-8	50.9	
		XI 1 D	12.6183	29.4167	+100	+2.0	+1.9	40 43 27.53	-7 4.53	-47	+	55 -15	22.93	+8	63.5	
		2	31.3583 ^{IV}	6.1143 ^{II}	-39	+1.3	+1.6	40 47 1.49	-10 37.48	-1.29	+	40 -24	22.88	+8	63.0	
		5	32.9390 ^{IV}	0.9913 ^{II}	-213	-.2	-.1	40 22 54.90	+13 26.35	+1.69	-	4 +25	23.15	+8	63.4	
		6	14.1367	24.9697	-29	+2.2	+1.9	40 31 49.04	+4 33.54	+43	+	58 +10	23.69	+8		
Sept. 3	I 1	7	21.6707	17.2907	-15	+1.7	+2.0	40 38 13.44	-1 50.59	-9	+	52 -3	23.25	+8	63.3	
		8	18.9703	21.2353	+2	-.9	-.2	40 37 20.37	-57.21	-2	-	16 -1	22.97	+8	63.2	
		1	22.5243	16.5410	-18	-.6	+1.2	40 33 51.85	+2 31.07	+26	+	6 +5	23.29	+8		
		2	27.5733	13.2003	+32	+1.3	+.1	40 42 26.61	-6 3.10	-42	+	22 -10	23.21	+8	62.9	
		3	23.4920	18.3630	+29	-1.6	-.2	40 34 13.26	+2 9.61	+23	-	28 +3	22.85	+7	63.3	
		4	18.8203	22.2493	+13	+2.3	+1.3	40 34 56.16	+1 26.64	+18	+	52 +3	23.53	+7		
		5	17.7293	22.4007	0	+2.7	+1.3	40 34 24.81	+1 57.99	+22	+	58 +3	23.63	+7	62.9	
		6	19.3687	19.9217	0	+1.4	0	40 36 8.89	+13.97	+11	+	22 0	23.19	+6		
	IV 1 D	7	29.0497	10.4003	-31	-1.1	-.2	40 28 31.15	+7 50.94	+70	-	20 +15	22.74	+6	62.2	
		8	32.7397 ^{IV}	9.1403 ^{II}	+20	-.8	+1.5	40 26 25.74	+9 56.09	+1.40	+	6 +17	23.46	+6	c	
		9	26.5940	14.8123	+50	0	-.9	40 31 25.19	+4 57.69	+46	-	12 +8	23.30	+6	60.2	
		10	14.3807	25.8050	+6	+1.0	+1.8	40 41 12.06	-4 48.55	-25	+	38 -11	23.53	+4	60.4	
		1	21.5230	18.7480	0	-.2	-.4	40 35 13.45	+1 10.09	+17	-	8 +2	23.65	-3	58.2	
		2	14.6943	26.0723	+25	0	+.2	40 41 10.92	-4 47.44	-32	+	2 -8	23.10	-2	58.4	
		4	29.4653 ^{IV}	10.9557 ^{II}	0	-.2	0	40 44 12.33	-7 47.51	-1.11	-	3 -14	23.54	-2		
		5	19.7220	15.5303	-58	-2.0	-.2	40 34 37.74	+1 45.72	+19	-	34 +3	23.34	-3	58.1	
		6	16.3787	23.5117	0	-.3	-1.6	40 39 24.01	-3 0.16	-19	-	25 -5	23.36	-3	57.9	

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Sept. 6	XI 1 D		28.8890	12.1347	+ 50	-1.5	-1.3	40 43 27.57	- 7 3.27	- 46	- 40	-15	40 36 23.29	+8	65.4
		2	8.4363 ⁱⁱ	33.6057 ^{iv}	+ 31	- .6	-1.4	40 47 1.67	-10 35.77	-1.29	- 28	-24	24.09	+8	64.4
		3	8.4357 ⁱⁱ	32.6710 ^{iv}	+ 15	+ .2	+2.6	40 26 9.11	+10 12.13	+1.43	+ 36	+18	23.21	+9	
		4	8.2987 ⁱⁱ	32.3597 ^{iv}	+ 9	0	- .1	40 26 13.81	+10 7.72	+1.42	- 2	+18	23.11	+9	63.8
		5	2.5320 ⁱⁱ	34.4627 ^{iv}	-106	- .3	- .5	40 22 55.19	+13 26.18	+1.69	- 11	+25	23.20	+8	
Sept. 8	I	6	26.0910	15.2710	+ 43	-1.2	-1.6	40 31 49.36	+ 4 33.38	+ 43	- 39	+10	22.88	+8	63.8
		7	19.2597	23.6260	+ 38	+ .1	+ .3	40 38 13.83	- 1 50.38	- 9	+ 6	- 3	23.39	+8	
		8	21.2337	18.9377	0	+1.3	+ .2	40 37 20.80	- 57.99	- 2	+ 22	- 1	23.00	+8	63.3
		1	15.9910	21.9413	+ 38	+ .2	+1.2	40 33 52.33	+ 2 30.38	+ 26	+ 18	+ 5	23.20	+8	62.9
		2	13.7580	28.1337	+ 78	-1.0	- .8	40 42 27.13	- 6 3.27	- 42	- 26	-10	23.08	+8	
		3	18.4583	23.5363	+ 33	+1.4	+1.4	40 34 13.83	+ 2 8.33	+ 23	+ 40	+ 3	22.82	+8	
		4	21.8943	18.4887	+ 4	- .9	- .1	40 34 56.79	+ 1 26.02	+ 17	- 16	+ 3	22.85	+7	63.1
	XI 1 D	5	23.2667	18.6260	+ 29	+1.0	+1.6	40 34 25.47	+ 1 57.28	+ 22	+ 36	+ 3	23.36	+7	62.6
		6	22.5537	22.0213	+ 8	- .8	0	40 36 9.51	+ 13.47	+ 11	- 12	+ 1	22.98	-6	
		7	10.9490	29.5427	+ 26	+2.2	+1.6	40 28 31.43	+ 7 49.68	+ 70	+ 54	+15	22.50	-6	62.4
		8	8.4287 ⁱⁱ	31.9767 ^{iv}	+ 4	+2.1	+1.7	40 26 26.49	+ 9 54.75	+1.40	+ 54	+17	23.35	+6	
		9	14.6147	26.3483	+ 32	+2.8	+1.3	40 31 25.97	+ 4 56.43	+ 46	+ 60	+ 8	23.54	+6	62.6
		10	28.2557	16.8177	+172	+2.1	+1.5	40 41 12.76	- 4 49.31	- 26	+ 52	-11	23.60	+5	62.4
		2	30.1987 ^{iv}	4.9540 ⁱⁱ	+100	- .3	-1.6	40 43 27.60	- 7 3.54	- 46	- 25	-15	23.20	+8	64.3
	I	3	32.6833 ^{iv}	8.4307 ⁱⁱ	+ 16	-2.2	-3.2	40 26 9.18	+10 12.58	+1.43	- 75	+18	22.62	+9	
		4	32.0707 ^{iv}	7.9843 ⁱⁱ	0	-1.7	-1.6	40 26 13.92	+10 8.35	+1.42	- 47	+18	23.40	+9	
		6	12.6573	23.4973	-123	-1.1	-1.6	40 31 49.48	+ 4 33.47	+ 42	- 38	+10	23.09	+8	61.6
		7	21.4173	17.0377	- 21	- .1	- .6	40 38 13.82	- 1 50.56	- 9	- 9	- 3	23.05	+9	60.9
		8	18.8157	21.1060	0	- .5	- .7	40 37 21.01	- 57.84	- 2	- 17	- 1	22.97	+8	61.6
		1	23.1190	17.1630	+ 5	-1.0	- .8	40 33 52.56	+ 2 30.44	+ 26	- 26	+ 5	23.05	+8	61.5
		2	27.8447	13.4597	+ 55	- .4	-2.0	40 42 27.39	- 6 3.46	- 42	- 32	-10	23.09	+8	
Sept. 9	IV 1 D	3	22.3217	17.2070	- 8	-1.4	- .8	40 34 14.12	+ 2 9.17	+ 23	- 32	+ 3	23.23	+8	61.5
		4	18.5693	21.9983	+ 5	- .8	-1.7	40 34 57.09	+ 1 26.62	+ 18	- 34	+ 3	23.58	+8	
		5	17.2563	21.9003	- 14	0	-1.1	40 34 25.81	+ 1 57.26	+ 22	- 14	+ 3	23.18	+7	60.4
		6	19.9607	20.4937	0	- .3	- .6	40 36 9.82	+ 13.46	+ 11	- 12	0	23.27	+6	59.9
		7	28.5050	9.8603	- 90	-2.1	-2.9	40 28 32.21	+ 7 50.68	+ 70	- 70	+15	23.04	+6	
		8	31.1760 ^{iv}	7.6163 ⁱⁱ	- 15	+1.1	+1.9	40 26 26.89	+ 9 55.00	+1.40	+ 41	+17	23.87	-6	
		9	25.3557	13.6113	- 36	-1.5	-1.0	40 31 26.39	+ 4 56.54	+ 45	- 36	+ 8	23.10	+6	59.9
	I	10	14.1667	25.6517	- 6	- .9	- .3	40 41 13.13	- 4 50.06	- 26	- 18	-11	22.52	+5	59.1
		1	22.9080	20.1960	+ 24	-1.6	-1.0	40 35 14.72	+ 1 8.56	+ 17	- 38	+ 2	23.09	-1	54.9
		2	14.6573	26.0693	+ 25	-1.0	- .8	40 41 12.21	- 4 48.31	- 32	- 26	- 8	23.24	-1	
		3	27.9647 ^{iv}	8.4097 ⁱⁱ	+ 4	+1.0	- .4	40 44 33.56	- 8 13.93	-1.12	+ 10	-17	23.44	-2	54.9
		4	29.3190 ^{iv}	10.7610 ⁱⁱ	0	- .4	-1.7	40 44 13.08	- 7 48.74	-1.11	- 28	-14	22.81	-2	54.8
		5	19.9633	15.8183	- 52	-3.2	-2.0	40 34 38.84	+ 1 44.56	+ 19	- 75	+ 3	22.87	-2	
		6	16.3757	23.5773	0	- .2	- .1	40 39 25.06	- 3 1.90	- 19	- 4	- 5	22.88	-2	
	XI 1 R	7	3.8607 ⁱⁱ	29.2927 ^{iv}	-110	- .4	- .1	40 25 39.66	+10 42.09	+1.51	- 8	+25	23.43	-2	53.9d
		8	12.2633	24.7083	-111	- .8	-1.5	40 41 38.35	- 5 14.06	- 34	- 32	-10	23.53	-3	53.7
		9	25.3760	12.4683	- 81	+ .5	+1.6	40 30 57.04	+ 5 25.82	+ 50	+ 28	+10	23.74	-3	
		10	30.6280 ^{iv}	9.1747 ⁱⁱ	0	- .1	+ .3	40 27 19.62	+ 9 1.86	+1.34	+ 2	+17	23.01	-3	53.9
		1	28.0157	11.2607	- 36	- .9	-1.4	40 43 27.59	- 7 3.08	- 46	- 32	-15	23.58	+8	63.0
		2	8.5160 ⁱⁱ	33.7183 ^{iv}	+ 34	- .6	- .6	40 47 1.72	-10 36.61	-1.29	- 17	-24	23.41	+8	62.9
		3	9.2330 ⁱⁱ	33.4823 ^{iv}	+ 34	+2.4	+ .7	40 26 9.22	+10 11.94	+1.43	+ 46	+18	23.23	+9	
Sept. 9	I	4	8.2990 ⁱⁱ	32.3667 ^{iv}	+ 9	+ .7	- .1	40 26 13.94	+10 7.89	+1.42	+ 10	+18	23.53	+9	
		5	2.5460 ⁱⁱ	34.4813 ^{iv}	-105	+ .6	- .1	40 22 55.35	+13 26.30	+1.70	+ 8	+25	23.68	+9	62.4
		6	26.3983	15.5910	+ 64	-1.0	- .7	40 31 49.55	+ 4 33.11	+ 43	- 24	+10	22.95	+8	62.4
		7	18.4823	22.8727	+ 18	+ .5	+ .7	40 38 14.09	- 1 50.94	- 9	+ 16	- 3	23.19	+9	62.3
		8	21.7920	19.4833	+ 8	+2.1	+ .9	40 37 21.10	- 58.33	- 2	+ 44	- 1	23.18	+8	
	I	1	17.8630	23.7893	+ 29	+ .2	+ .9	40 33 52.67	+ 2 29.75	+ 26	+ 14	+ 5	22.87	+8	
		2	13.4840	27.8850	+ 57	+ .2	+ .6	40 42 27.50	- 6 3.86	- 43	+ 10	-10	23.21	+8	63.4

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Sept. 9	I	3 R	18.3623	23.4500	+ 28	+1.4	+2.4	40 34 14.25	+ 2 8 56	+ 23	+ 52	+ 3	40 36 23.59	+8	62.8
			23.0733	19.6947	+ 27	-1.3	+ .7	40 34 57.14	+ 1 25.40	+ 17	- 11	+ 3	22.63	+8	62.8
			23.1487	18.5340	+ 25	-1.0	+ .4	40 34 25.97	+ 1 56.61	+ 21	- 10	+ 3	22.72	+7	
			20.8577	20.3567	0	0	+ .4	40 36 9.98	+ 12.66	+ 11	+ 5	0	22.80	+6	62.5
			11.0243	29.6050	+ 34	+ .7	0	40 28 32.38	+ 7 49.37	+ 69	+ 11	+15	22.70	+7	
Sept. 12	XI	2 D	9.0907 ^{II}	32.6250 ^{IV}	+ 18	+ .9	- .1	40 26 27.08	+ 9 54.43	+1.40	+ 12	+17	23.20	+7	
			14.4227	26.1293	+ 19	+1.3	+ .4	40 31 26.59	+ 4 55.71	+ 45	+ 25	+ 8	23.08	+6	62.4
			32.0857 ^{IV}	6.8653 ^{II}	- 18	-1.1	- .7	40 47 1.83	-10 36.93	-1.29	- 26	-24	23.11	+8	61.6
			32.5263 ^{IV}	8.2943 ^{II}	+ 12	+ .1	-1.7	40 26 9.40	+10 12.04	+1.43	- 20	+18	22.85	+9	
			32.1820 ^{IV}	0.2533 ^{II}	-266	+ .6	+ .4	40 22 55.57	+13 25.74	+1.69	+ 14	+25	23.39	+9	61.9
	I	2	14.1950	24.9920	- 26	- .7	-1.3	40 31 49.79	+ 4 32.63	+ 43	- 28	+10	22.67	+9	
			22.0317	17.6343	- 6	+ .4	- .2	40 38 14.38	- 1 51.05	- 9	+ 4	- 3	23.25	+9	62.2
			18.9220	21.2023	0	-2.1	-2.5	40 37 21.44	- 57.59	- 2	- 64	- 1	23.18	+9	
			22.6637	16.7403	- 11	- .8	- .3	40 33 53.04	+ 2 29.58	+ 26	- 16	+ 5	22.77	+9	61.9
			27.7100	13.3073	+ 42	- .6	-2.0	40 42 27.50	- 6 3.87	- 43	- 35	-10	22.75	+8	
Sept. 16	XI	2 R	22.8937	17.8213	+ 12	- .5	0	40 34 14.69	+ 2 8.14	+ 23	- 8	+ 3	23.01	+8	61.9
			18.9493	22.3440	+ 12	- .4	-1.1	40 34 57.72	+ 1 25.77	+ 17	- 20	+ 3	23.49	+8	
			18.2340	22.8683	+ 15	- .2	-1.1	40 34 26.47	+ 1 57.09	+ 22	- 17	+ 3	23.64	+9	
			19.4577	19.9667	0	-1.6	- .2	40 36 10.45	+ 12.86	+ 11	- 28	+ 1	23.15	+7	60.9
			29.2500	10.6443	- 8	-1.7	-2.5	40 28 32.91	+ 7 49.89	+ 70	- 58	+15	23.07	+7	
	I	2	32.3317 ^{IV}	8.8140 ^{II}	+ 12	- .8	-1.0	40 26 27.67	+ 9 54.01	+1.40	- 25	+17	23.00	+7	60.9
			7.9217 ^{II}	33.1220 ^{IV}	+ 17	- .3	- .9	40 47 2.07	-10 36.51	-1.29	- 16	-24	23.87	+8	64.4
			9.2383 ^{II}	33.4533 ^{IV}	+ 32	+ .3	- .1	40 26 9.72	+10 11.66	+1.43	+ 3	+18	23.02	+9	63.9
			9.2603 ^{II}	33.3207 ^{IV}	+ 31	-1.7	-1.3	40 26 14.49	+10 7.76	+1.42	- 43	+18	23.42	+9	
			1.8200 ^{II}	33.7447 ^{IV}	-156	- .8	-2.0	40 22 55.96	+13 25.90	+1.69	- 38	+25	23.42	+9	63.9
Sept. 17	IV	2 R	25.7473	14.9530	+ 22	-1.6	-1.8	40 31 50.21	+ 4 32.68	+ 43	- 48	+10	22.94	+9	
			19.3787	23.7870	+ 41	- .7	+ .3	40 38 14.91	- 1 51.45	- 9	- 7	- 3	23.27	+9	
			22.5163	20.2080	+ 18	- .5	-1.8	40 37 22.00	- 58.34	- 2	- 30	- 1	23.33	+9	α
			17.7633	23.6637	+ 24	- .3	0	40 33 53.64	+ 2 29.08	+ 26	- 4	+ 5	22.99	+9	62.6
			13.1730	27.6187	+ 35	- .2	-1.7	40 42 28.56	- 6 4.93	- 43	- 24	-10	22.86	+9	62.1
	I	2	18.5827	23.6423	+ 34	- .9	- .5	40 34 15.41	+ 2 7.87	+ 23	- 20	+ 3	23.34	+8	
			22.3640	19.0067	+ 14	0	-1.0	40 34 58.47	+ 1 24.83	+ 17	- 12	+ 3	23.38	+8	61.9
			22.6987	18.0997	+ 12	-1.4	-1.0	40 34 27.28	+ 1 56.18	+ 21	- 34	+ 3	23.36	+8	61.6
			26.0597	14.5750	+ 22	+1.3	+ .4	40 41 14.09	- 4 50.14	- 33	+ 25	- 8	23.79	0	55.4
			11.6017 ^{II}	31.2463 ^{IV}	- 4	- .7	- .2	40 44 40.20	- 8 16.17	-1.12	- 14	-17	22.60	-1	55.4d
Sept. 19	IV	2 R	11.0313 ^{II}	29.6633 ^{IV}	0	- .7	+ .3	40 44 15.14	- 7 50.61	-1.12	- 7	-14	23.20	-1	
			20.5997	24.6303	+ 62	+2.1	+1.6	40 34 40.39	+ 1 41.96	+ 19	+ 53	+ 3	23.10	-2	54.4
			24.5557	17.2960	+ 38	+ .8	+ .3	40 39 26.54	- 3 3.46	- 19	+ 16	- 5	23.00	-2	
			33.7780 ^{IV}	8.4283 ^{II}	+ 35	-1.4	-1.3	40 25 40.85	+10 40.36	+1.51	- 38	+25	22.59	-2	54.1
			27.9110	15.4243	+121	+2.0	+ .6	40 41 39.46	- 5 15.70	- 34	+ 38	-10	23.70	-2	
	I	2 D	20.6383	18.0257	- 10	+ .2	0	40 35 17.08	+ 1 5.96	+ 17	+ 3	+ 2	23.26	0	67.1
			12.9167	24.4630	- 89	+ .7	+ .5	40 41 14.63	- 4 51.39	- 33	+ 18	- 8	23.01	0	66.7
			30.7853 ^{IV}	11.1400 ^{II}	0	- .1	+ .2	40 44 40.67	- 8 16.15	-1.12	+ 1	-17	23.24	-1	
			29.9403 ^{IV}	11.2840 ^{II}	- 5	+ .2	+ .3	40 44 15.61	- 7 51.17	-1.12	+ 7	-14	23.25	-1	
			22.5953	18.5607	+ 15	- .9	+ .2	40 34 40.84	+ 1 41.93	+ 19	- 12	+ 3	22.87	-1	66.6
Sept. 20	IV	1 R	4.8510 ^{II}	30.2013 ^{IV}	- 77	- .1	0	40 25 41.21	+10 40.05	+1.51	- 2	+25	23.00	-2	66.0
			13.2157	25.7837	- 37	+1.3	+1.7	40 41 39.81	- 5 17.32	- 34	+ 42	-10	22.47	-2	66.2
			19.5463	22.1737	+ 13	-1.7	-2.3	40 35 17.34	+ 1 6.39	+ 17	- 56	+ 2	23.36	0	57.6
			26.7037	15.1987	+ 64	+ .2	+1.0	40 41 14.63	- 4 50.74	- 33	+ 16	- 8	23.64	0	
			11.1880 ^{II}	30.7670 ^{IV}	0	-1.8	-1.2	40 44 40.91	- 8 15.78	-1.12	- 44	-17	23.40	-1	58.8
	I	2	11.2947 ^{II}	29.9447 ^{IV}	- 6	-3.6	- .6	40 44 15.84	- 7 51.04	-1.12	- 64	-14	22.90	-1	
			23.2503	27.2463	+125	+1.2	+ .1	40 34 41.07	+ 1 41.24	+ 19	+ 20	+ 3	22.73	-1	57.4
			24.1447	16.9260	+ 23	-1.2	-1.5	40 39 27.19	- 3 2.38	- 19	- 38	- 5	24.19	-1	
			32.5473 ^{IV}	7.2057 ^{II}	- 4	-1.9	- .8	40 25 41.40	+10 40.05	+1.51	- 40	+25	22.81	-1	
			28.2203	15.7377	+144	- .3	-1.0	40 41 39.99	- 5 15.64	- 34	- 17	-10	23.74	-2	56.6

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Sept. 20	IV 9 R		14.7240	27.5737	+ 89	+ .2	— .6	40 30 58.54	+ 5 24.77	+ 50	— 4	+10	40 36 23.87	—2	
		10	10.0707 ^{II}	31.4963 ^{IV}	+ 7	+1.1	— .5	40 27 20.95	+ 9 1.17	+1.34	+ 10	+17	23.73	—2	56.6
	V 1		28.5160	12.6090	+ 51	—3.2	— .2	40 29 40.24	+ 6 41.90	+ 60	— 52	+11	22.33	—2	56.6
		2	18.6530	23.2260	+ 26	— .1	0	40 38 18.93	— 1 55.57	— 9	— 2	— 3	23.22	—3	56.7
		3	10.3907 ^{II}	33.9510 ^{IV}	+ 46	— .8	— .3	40 26 26.29	+ 9 55.19	+1.47	— 16	+23	23.02	—2	d
	4		14.7700	29.2033	+167	—1.3	—1.4	40 42 29.32	— 6 4.97	— 42	— 38	—11	23.44	—3	
	5		33.3567 ^{IV}	9.8037 ^{II}	+ 34	—2.9	— .2	40 26 27.25	+ 9 54.98	+1.42	— 48	+19	23.36	—3	55.5
	6		23.0443	22.0013	+ 17	+ .7	— .3	40 36 49.68	— 26.39	+ 9	+ 7	— 1	23.44	—3	
	7		13.6143	28.4457	+ 89	—2.0	+ .5	40 42 38.86	— 6 14.83	— 42	— 24	—12	23.25	—3	
	Sept. 21 IV 1 D		21.2007	18.5860	0	— .7	—1.3	40 35 17.58	+ 1 6.05	+ 17	— 28	+ 2	23.54	0	52.6
	2		13.7667	25.2983	— 32	—2.0	—2.2	40 41 15.13	— 4 51.19	— 33	— 59	— 8	22.94	0	
	3		28.8543 ^{IV}	9.1810 ^{II}	0	—1.3	—1.5	40 44 41.13	— 8 16.91	—1.12	— 39	—17	22.54	0	52.4
	4		30.1463 ^{IV}	11.4957 ^{II}	— 7	— .6	—1.3	40 44 16.07	— 7 51.07	—1.12	— 26	—14	23.48	—1	52.2
	5		22.5713	18.5397	+ 13	—1.2	— .5	40 34 41.28	+ 1 41.86	+ 19	— 25	+ 3	23.11	—1	
	6		17.8233	25.0887	+ 62	—1.7	—1.1	40 39 27.41	— 3 3.67	— 19	— 40	— 5	23.10	—1	51.8
	8		12.7937	25.3140	— 69	— .7	— .4	40 41 40.16	— 5 16.06	— 34	— 16	—10	23.50	—2	51.9
	9		26.7080	13.8717	+ 23	—1.9	— .7	40 30 58.71	+ 5 24.28	+ 50	— 38	+10	23.21	—2	
	10		30.5980 ^{IV}	9.1870 ^{II}	0	— .4	— .3	40 27 21.11	+ 9 0.81	+1.34	— 10	+17	23.33	—2	
	V 1		11.9567	27.8633	— 8	+ .6	— .1	40 29 40.38	+ 6 41.76	+ 60	+ 8	+11	22.93	—2	51.3
	2		23.8790	19.2703	+ 43	+1.6	+1.6	40 38 19.11	— 1 56.51	— 9	+ 46	— 3	22.94	—3	
Sept. 22	IV 1 R		31.1553 ^{IV}	7.5743 ^{II}	— 15	—1.4	0	40 26 26.40	+ 9 55.58	+1.47	— 22	+23	23.46	—2	
		2	19.3177	21.8973	+ 9	— .8	+1.7	40 35 17.72	+ 1 5.17	+ 17	+ 9	+ 2	23.17	0	56.5
	3		26.6190	15.0837	+ 58	+ .7	—1.4	40 41 15.58	— 4 51.50	— 33	— 7	— 8	23.60	0	
	4		11.2370 ^{II}	31.9300 ^{IV}	— 4	— .8	— .8	40 44 41.53	— 8 17.39	—1.05	— 22	—17	22.70	0	56.4
			11.2080 ^{II}	29.9270 ^{IV}	+ 6	+1.0	+1.0	40 44 16.48	— 7 52.78	—1.05	+ 28	—14	22.79	—1	55.6
	5		18.8803	22.8993	+ 21	+1.2	— .2	40 34 41.69	+ 1 41.56	+ .19	+ 16	+ 3	23.63	—1	
	6		25.3697	18.0827	+ 77	— .4	0	40 39 27.79	— 3 4.25	— 20	— 6	— 5	23.23	—1	
	7		34.6610 ^{IV}	9.3477 ^{II}	+ 63	—1.0	— .9	40 25 41.91	+10 39.52	+1.43	— 27	+25	22.84	—1	56.2
	8		27.6550	15.1517	+105	—1.0	—1.0	40 41 40.48	— 5 16.07	— 34	— 28	—10	23.69	—2	56.0
	9		14.7143	27.5057	+ 82	+2.0	+ .6	40 30 59.01	+ 5 23.28	+ 50	+ 38	+10	23.27	—2	
	V 10		11.9420 ^{II}	33.3263 ^{IV}	+ 24	+ .8	— .2	40 27 21.39	+ 9 0.18	+1.27	+ 10	+17	23.11	—2	
		1	29.7400	13.8513	+166	—3.1	—1.6	40 29 40.67	+ 6 41.73	+ 60	— 68	+11	22.43	—2	
	2		18.7050	23.3033	+ 28	0	— .4	40 38 19.30	— 1 56.21	— 9	— 5	— 3	22.92	—2	55.1
	4		27.0210	12.5483	— 21	+ .2	— .4	40 42 29.61	— 6 5.49	— 42	— 2	—11	23.57	—3	55.2
	5		7.0733 ^{II}	30.6263 ^{IV}	— 24	+ .7	+ .7	40 26 27.52	+ 9 54.83	+1.35	+ 20	+19	24.09	—3	
	6		18.8070	19.8743	— 5	—1.1	— .7	40 36 49.89	— 26.95	+ 9	— 26	— 1	22.76	—2	55.0
	7		27.9570	13.0867	+ 45	+1.7	+ .7	40 42 39.04	— 6 15.70	— 42	+ 36	—12	23.16	—3	
	8		22.7237	18.1943	+ 12	— .7	— .4	40 34 28.46	+ 1 54.43	+ 23	— 16	+ 4	23.00	—3	
	Sept. 27 I 2 D		27.7683	13.3067	+ 46	— .1	— .8	40 42 29.56	— 6 5.40	— 49	— 12	—10	23.45	+9	50.2
	3		23.7950	18.8000	+ 39	— .7	— .2	40 34 16.59	+ 2 6.27	+ 25	— 14	+ 3	23.00	+9	
	4		19.5550	22.8560	+ 23	+1.3	— .1	40 34 59.81	+ 1 23.44	+ 19	+ 18	+ 3	23.65	+9	49.6
	5		17.8337	22.3470	0	+ .8	+ .5	40 34 28.76	+ 1 54.00	+ 23	+ 19	+ 3	23.21	+9	50.0
	6		19.7210	20.1470	0	— .1	—1.9	40 36 12.64	+ 10.76	+ 11	— 26	0	23.25	+8	
	7		29.7663	11.3113	+ 58	—1.0	— .1	40 28 35.41	+ 7 46.30	+ 77	— 17	+15	22.46	+8	
	8		32.3770 ^{IV}	8.9697 ^{II}	+ 15	+1.4	+1.2	40 26 30.42	+ 9 51.28	+1.37	+ 37	+17	23.61	+8	50.2
	9		25.6093	14.0153	— 14	— .1	— .4	40 31 30.10	+ 4 52.82	+ 50	— 6	+ 8	23.44	+8	
	10		13.9743	25.5833	— 12	—1.2	— .4	40 41 16.43	— 4 53.20	— 31	— 24	—13	22.55	+6	49.6
	II 2		19.1243	19.9077	— 3	+ .6	+ .5	40 36 42.38	— 19.78	+ 7	+ 16	0	22.83	+6	48.4
	4		22.0410	17.2523	— 13	+ .7	— .8	40 38 24.04	— 2 0.93	— 8	+ 1	— 3	23.01	+6	a
	5		11.7290 ^{II}	29.0023 ^{IV}	— 6	— .5	— .4	40 29 5.50	+ 7 16.29	+1.13	— 12	+12	22.92	+6	48.2a
Sept. 28	6		30.2797 ^{IV}	10.5453 ^{II}	0	—1.0	— .1	40 28 3.58	+ 8 18.48	+1.22	— 17	+14	23.25	+6	
	7		13.0347 ^{II}	28.4167 ^{IV}	— 20	+ .5	—1.3	40 29 53.85	+ 6 28.48	+1.05	— 9	+11	23.40	+6	
	8		27.0200	11.4127	— 74	+1.4	— .3	40 42 58.19	— 6 34.04	— 52	+ 18	—11	23.70	+5	
	9		17.6263	20.5270	— 16	— .2	+1.1	40 37 35.99	— 1 13.23	+ 1	+ 11	— 2	22.86	+4	48.3
	I 12		13.4670	27.9367	+ 59	+1.1	+ .7	40 42 29.67	— 6 5.63	— 49	+ 26	—10	23.71	+9	51.9

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude			Δ	Ther.
						A	B		Micrometer	δ	l	r					
Sept. 28	I	3 D	19.5267	24.5493	+ 60	-2.2	-2.4	40 34 16.72	+ 2 7.01	+ 25	- 64	+ 3	40 36 23.37	+ 8	51.5		
			23.0000	19.6937	+ 26	-2.8	-2.2	40 34 59.95	+ 1 23.58	+ 19	- 72	+ 3	23.03	+ 8			
			21.8747	17.3313	- 12	-1.9	- .9	40 34 28.92	+ 1 54.73	+ 23	- 41	+ 3	23.50	+ 9			
			22.1217	21.7373	+ 6	+1.7	+1.9	40 36 12.78	+ 9.72	+ 10	+ 50	0	23.10	+ 8	51.2		
	II	4	11.5767	30.0217	+ 85	+ .8	+ .3	40 28 35.58	+ 7 46.11	+ 77	+ 16	+15	22.77	+ 8			
			9.3980 ⁱⁱ	32.8053 ^{iv}	+ 22	+1.2	- .3	40 26 30.61	+ 9 51.29	+1.37	+ 14	+17	23.58	+ 8	51.1		
			27.5210	15.9350	+118	+ .1	+ .1	40 41 16.61	- 4 52.95	- 31	+ 3	-13	23.25	+ 6			
			18.2543	19.5707	- 7	- .6	- .3	40 36 56.49	- 33.23	+ 8	- 14	- 1	23.19	+ 6			
	II	2	20.8690	20.0917	+ 3	+1.1	+1.5	40 36 42.59	- 19.64	+ 7	+ 36	0	23.38	+ 6			
			19.1540	23.9600	+ 44	- .2	- .5	40 38 24.26	- 2 1.50	- 8	- 10	- 3	22.55	+ 6	50.4		
Sept. 29	I	5 D	28.9383 ^{iv}	11.6770 ⁱⁱ	- 6	-2.4	- .8	40 29 5.75	+ 7 15.98	+1.13	- 47	+12	22.51	+ 6			
			10.4350 ⁱⁱ	30.1353 ^{iv}	0	+2.5	+2.5	40 28 3.83	+ 8 17.60	+1.22	+ 70	+14	23.49	+ 6	49.3		
			28.6610 ^{iv}	13.3170 ⁱⁱ	- 28	+ .6	0	40 29 54.10	+ 6 27.49	+1.05	+ 10	+11	22.85	+ 6	50.1		
			27.5997	13.0967	+ 31	+3.1	+2.3	40 42 29.79	- 6 6.41	- 49	+ 78	-10	23.57	+ 9	51.8 ^b		
	II	3	23.7487	18.7777	+ 40	+ .3	+ .9	40 34 16.85	+ 2 5.67	+ 25	+ 16	+ 3	22.96	+ 9			
			19.4387	22.7133	+ 20	+1.6	+ .1	40 35 0.10	+ 1 22.77	+ 18	+ 26	+ 3	23.34	+ 9	51.5		
			18.1453	22.6570	+ 13	+ .2	- .9	40 34 29.08	+ 1 54.00	+ 23	- 8	+ 3	23.26	+ 9			
			18.4407	18.8223	- 4	+1.1	- .1	40 36 12.95	+ 9.63	+ 10	+ 16	0	22.84	+ 8	51.1		
	II	7	30.1383	11.7117	+100	+ .5	+1.0	40 28 35.76	+ 7 45.69	+ 77	+ 20	+15	22.57	+ 8			
			32.3193 ^{iv}	8.9670 ⁱⁱ	+ 13	+1.1	+3.4	40 26 30.81	+ 9 49.88	+1.36	+ 60	+17	22.82	+ 8	50.4		
			25.9837	14.4420	+ 13	+1.6	+1.4	40 31 30.51	+ 4 51.56	+ 50	+ 43	+18	23.18	+ 8			
			13.1683	24.8223	- 70	+ .4	+ .8	40 41 16.83	- 4 54.19	- 31	+ 16	-13	22.36	+ 6	50.1		
	II	10	20.4793	19.1573	0	-1.4	-2.0	40 36 56.59	- 33.39	+ 8	- 47	- 1	22.80	+ 6			
			18.6597	19.4523	- 3	- .4	+ .3	40 36 42.80	- 20.01	+ 7	- 2	- 1	22.83	+ 6			
			10.8613	27.5967	- 75	+ .9	0	40 29 19.60	+ 7 2.52	+ 70	+ 14	+13	23.09	+ 7	49.5		
	II	4	22.5390	17.7097	0	+ .6	- .2	40 38 24.49	- 2 1.99	- 8	+ 7	- 3	22.46	+ 6	49.6		
			11.3097 ⁱⁱ	28.5583 ^{iv}	0	+2.3	+ .8	40 29 6.01	+ 7 15.67	+1.13	+ 46	+12	23.39	+ 6			
			31.6503 ^{iv}	11.9567 ⁱⁱ	- 3	- .4	+1.4	40 28 4.10	+ 8 17.43	+1.22	+ 12	+14	23.01	+ 6	49.1		
			14.1757 ⁱⁱ	29.5133 ^{iv}	- 51	+1.3	+ .8	40 29 54.38	+ 6 27.28	+1.05	+ 30	+11	23.12	+ 6			
	V	8	28.3907	12.7603	+ 52	+1.7	+ .2	40 42 58.71	- 6 34.94	- 52	+ 29	-11	23.43	+ 5			
			19.6037	22.5100	+ 17	- .2	+ .7	40 37 36.47	- 1 13.46	+ 1	+ 6	- 2	23.06	+ 4	49.1		
			28.6147	12.7603	+ 64	+ .7	+ .4	40 29 41.25	+ 6 40.64	+ 66	+ 16	+11	22.82	- 2	45.7		
			18.9317	23.5413	+ 34	+ .8	- .3	40 38 19.77	- 1 56.52	- 11	+ 8	- 3	23.19	- 2	45.6		
	V	3	9.9040 ⁱⁱ	33.4557 ^{iv}	+ 36	- .6	+ .2	40 26 26.90	+ 9 55.00	+1.44	+ 7	+24	23.51	- 2			
			13.2317	27.7237	+ 41	-2.1	- .2	40 42 29.95	- 6 6.17	- 48	- 35	-11	22.84	- 2			
			32.1460 ^{iv}	8.5583 ⁱⁱ	+ 8	-2.4	-1.6	40 26 27.75	+ 9 55.84	+1.18	- 58	+19	24.38	- 2	44.6*		
			22.3390	21.2967	+ 11	0	- .9	40 36 49.99	- 26.36	+ 9	- 12	- 1	23.59	- 2			
	II	7	14.6293	29.4640	+178	-1.8	- .4	40 42 39.10	- 6 15.17	- 48	- 33	-12	23.00	- 3	44.8		
			18.5677	23.0987	+ 25	- .3	- .4	40 34 28.43	+ 1 54.51	+ 25	- 10	+ 4	23.13	- 3	44.5		
			13.3943	27.2333	+ 25	-1.6	-1.4	40 42 13.89	- 5 49.63	- 46	- 43	- 9	23.28	- 3			
			23.5420	20.3973	+ 37	+2.1	+ .9	40 37 43.23	- 1 19.53	- 5	+ 44	- 3	24.06	- 3	43.9		
Sept. 30	I	2 R	12.5993	27.0997	- 13	+ .7	- .8	40 42 29.89	- 6 6.23	- 49	+ 1	-10	23.08	+ 9	50.4		
			18.3863	23.3873	+ 27	0	- .5	40 34 16.97	+ 2 6.39	+ 25	- 6	+ 3	23.58	+ 9			
			23.1290	19.8493	+ 29	-1.0	- .8	40 35 0.24	+ 1 22.92	+ 18	- 26	+ 3	23.11	+ 9	51.0		
			24.1943	19.6960	+ 52	-1.8	-1.1	40 34 29.24	+ 1 53.76	+ 23	- 42	+ 3	22.84	+ 9			
	II	6	22.5923	22.1823	+ 6	-1.3	-1.0	40 36 13.11	+ 10.37	+ 10	- 32	0	23.26	+ 8	51.0		
			11.8447 ⁱⁱ	30.2907 ^{iv}	- 9	+ .1	- .1	40 28 35.93	+ 7 45.90	+1.19	0	+15	23.17	+ 8			
			9.2243 ⁱⁱ	32.6107 ^{iv}	+ 18	+2.4	+ .1	40 26 30.99	+ 9 50.76	+1.37	+ 38	+17	23.67	+ 8			
			15.3503	26.8967	+ 78	+2.4	+ .2	40 31 30.71	+ 4 51.85	+ 50	+ 40	+ 8	23.54	+ 8	51.0		
	II	10	27.2777	15.6893	+101	+1.1	+ .2	40 41 16.99	- 4 52.96	- 31	+ 20	-13	23.79	+ 6			
			22.0733	23.4087	+ 23	+1.5	+ .1	40 36 56.79	- 33.79	+ 8	+ 24	- 1	23.31	+ 6			
			23.3370	22.5350	+ 12	+1.8	+ .8	40 36 43.01	- 20.29	+ 7	+ 38	- 1	23.16	+ 6	50.2		
			29.1037	12.3933	+ 71	- .8	- .3	40 29 19.84	+ 7 2.26	+ 70	- 16	+13	22.77	+ 7	49.8		
	II	4	18.4017	23.2030	+ 25	-1.1	-2.1	40 38 24.72	- 2 1.34	- 8	- 44	- 3	22.83	+ 7			
			30.4173 ^{iv}	13.1503 ⁱⁱ	- 28	+ .2	-1.0	40 29 6.27	+ 7 16.07	+1.13	- 10	+12	23.49	+ 7			

* Turned in Azimuth.

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude			Δ	Ther.	
						A	B		Micrometer	δ	l	r						
Sept. 30	II 6 R		10.8307 ¹¹	30.5327 ^{1v}	0	+	.6	— .2	40 28 4.37	+ 8 17.65	+1.22	+	7	+14	40 36 23.45	+6	48.7	
			28.6853 ^{1v}	13.3500 ¹¹	— 32	+	.5	0	40 29 54.65	+ 6 27.27	+1.05	+	8	+11	23.16	+6		
			12.1377	27.7577	— 4	—	0	— .2	40 42 58.99	— 6 34.54	— 52	—	2	—11	23.80	+6		
	V 1 D		23.5970	20.7247	+ 37	—1.4	—1.6	40 37 36.72	— 1 12.65	+	1	— 42	— 2	23.64	+5	48.5		
			12.3833	28.2697	+ 29	— .3	—1.3	40 29 41.38	+ 6 41.36	+	66	— 21	+11	23.30	—2	45.6		
			21.8730	17.2623	— 14	+	.3	0	40 38 19.87	— 1 56.43	— 11	+	4	— 3	23.34	—2	44.4	
			31.5233 ^{1v}	7.9763 ¹¹	— 6	— .2	—1.0	40 26 26.97	+ 9 54.78	+1.44	— 16	+24	23.27	—2				
			27.5417	13.0840	+ 27	+1.5	0	40 42 30.01	— 6 5.27	— 48	+	23	—11	24.38	—2			
			7.7473 ¹¹	31.2983 ^{1v}	— 12	+	.1	—1.6	40 26 27.82	+ 9 54.86	+1.39	— 19	+19	24.07	—2	45.0		
			18.9887	20.0720	— 3	—2.7	—1.3	40 36 50.01	— 27.36	+	9	— 58	— 1	22.15	—2	44.9		
Oct. 1			27.5580	12.7150	+ 12	+	.2	—1.1	40 42 39.12	— 6 14.96	— 48	— 11	—12	23.45	—3			
			21.4873	16.9787	— 20	+1.7	+.6	40 34 28.43	+ 1 53.84	+	25	+	34	+ 4	22.90	—3		
			25.8290	11.9930	— 87	+1.2	— .4	40 42 13.89	— 5 49.27	— 46	+	14	— 9	24.21	—3			
	I 2 D		19.1683	22.3300	+ 13	— .6	0	40 37 43.21	— 1 19.90	— 5	— 10	— 3	23.13	—3	44.4			
			28.0270	13.5150	+ 65	— .2	+2.9	40 42 29.98	— 6 6.70	— 49	+	34	—10	23.03	+9	57.9		
			22.2557	17.3020	— 8	+	.2	+1.5	40 34 17.08	+ 2 5.10	+	25	+	22	+ 3	22.68	+9	
			16.8730	20.1337	— 29	+2.3	+2.6	40 35 0.35	+ 1 22.28	+	18	+	68	+ 3	23.52	+9	57.5	
			17.5220	22.0133	— 8	+	.9	+.1	40 34 29.37	+ 1 53.42	+	23	+	16	+ 3	23.21	+9	
			20.1677	20.5627	0	+1.4	+.4	40 36 13.24	— 9.98	+	10	+	26	0	23.58	+8	56.4	
			30.0353	11.6120	+ 87	+	.6	+1.4	40 28 36.09	+ 7 45.56	+	77	+	28	+15	22.85	+8	
			31.7310 ^{1v}	8.3767 ¹¹	0	+1.0	+2.1	40 26 31.16	+ 9 49.88	+1.36	+	42	+17	22.99	+8			
			26.0273	14.4920	+ 14	+	.8	+1.2	40 31 30.90	+ 4 51.39	+	50	+	28	+ 8	23.15	+8	55.8
			14.7163	26.3540	+ 38	+1.3	+2.6	40 41 17.17	— 4 54.04	— 31	+	53	—13	23.22	+7	55.4		
	II 1		21.6140	20.2827	+ 7	+	.5	— .9	40 36 56.98	— 33.65	+	8	— 4	— 1	23.36	+6	54.9	
			20.4443	21.2507	+ 6	— .5	— .2	40 36 43.20	— 20.38	+	7	— 10	— 1	22.78	+6			
			11.3210	28.0287	— 33	+	.9	+.3	40 29 20.07	+ 7 1.92	+	70	+	18	+13	23.00	+7	54.4
			23.3237	18.4777	+ 26	+	.2	— .3	40 38 24.95	— 2 2.46	— 8	— 1	— 3	22.37	+6			
			11.2103 ¹¹	28.4340 ^{1v}	+ 4	+1.7	+1.2	40 29 6.52	+ 7 15.05	+1.13	+	42	+12	23.24	+7			
			30.8520 ^{1v}	11.1633 ¹¹	0	—1.5	—1.0	40 28 4.63	+ 8 17.29	+1.22	— 36	+14	22.92	+6	54.0			
			13.6863 ¹¹	29.0117 ^{1v}	— 38	+	.3	— .1	40 29 54.97	+ 6 26.99	+1.05	+	3	+11	23.15	+6		
V 8 R				27.9723	12.3373	+ 13	— .8	—1.2	40 42 59.26	— 6 34.94	— 52	— 28	—11	23.41	+6			
				18.8117	21.7450	+ 7	—1.8	+.8	40 37 36.98	— 1 14.10	+	1	— 18	— 2	22.69	+5	53.6	
	27.3980	11.5063		— 52	0	—1.2	40 29 41.41	+ 6 41.27	— 66	— 16	+11	23.29	—2	49.8				
		18.4037	23.0217	+ 21	+1.3	+.4	40 38 20.00	— 1 56.69	— 11	+	25	— 3	23.42	—2				
		10.2263 ¹¹	33.7867 ^{1v}	+ 42	—2.2	—1.8	40 26 27.06	+ 9 55.20	+1.44	— 57	+24	23.37	—2	50.3				
				13.6653	28.1327	+ 75	—2.7	—1.6	40 42 30.11	— 6 5.61	— 48	— 47	—11	23.44	—2	51.1		
34.8220 ^{1v}	11.3260 ¹¹			+ 64	— .7	0	40 26 27.89	+ 9 53.63	+1.39	— 11	+19	22.99	—2					
20.2920	19.2480			0	+.3	— .3	40 36 50.07	— 26.37	+	9	0	— 1	23.78	—2				
Oct. 2			13.3973	28.2497	+ 72	—2.7	0	40 42 39.16	— 6 15.33	— 48	— 26	—12	22.97	—3	51.1			
			17.1270	21.6747	— 17	— .8	—1.9	40 34 28.45	+ 1 54.82	+	25	— 36	+ 4	23.20	—3			
			12.8747	26.7193	— 15	— .9	— .1	40 42 13.90	— 5 49.66	— 46	— 16	— 9	23.53	—3				
	V 10 D		23.1357	20.0027	+ 29	+1.1	— .1	40 37 43.21	— 1 19.21	— 5	+	16	— 3	24.08	—3	50.6		
			12.7673	28.5863	+ 63	+1.7	+1.3	40 29 41.68	+ 6 39.71	+	66	+	43	+11	22.59	—2	53.6	
			23.4330	18.8267	+ 31	+.1	— .9	40 38 20.14	— 1 56.42	— 11	— 10	— 3	23.48	—2	53.9			
			31.2990 ^{1v}	7.7487 ¹¹	— 12	—2.4	— .7	40 26 27.17	+ 9 54.80	+1.44	— 46	+24	23.19	—2				
					27.8283	13.3567	+ 51	0	—1.6	40 42 30.21	— 6 5.66	— 48	— 20	—11	23.76	—2		
					7.1870 ¹¹	30.7507 ^{1v}	— 21	— .4	—3.2	40 26 27.99	+ 9 55.12	+1.39	— 47	+19	24.22	—2		
	20.1233	21.2033			+ 5	— .7	+1.2	40 36 50.13	— 27.29	+	9	+	4	— 1	22.96	—2	54.3	
Oct. 3			27.4310	12.5593	0	— .2	— .8	40 42 39.22	— 6 15.62	— 48	— 13	—12	22.87	—3	53.6			
			22.7840	18.2580	+ 17	+.1	+.3	40 34 28.49	+ 1 54.36	+	25	+	6	+ 4	23.20	—3		
			27.7390	13.8967	+ 66	+4.6	+3.3	40 42 13.93	— 5 49.80	— 46	+1.14	— 9	24.72	—3	53.2			
	I 10 R		18.0300	21.2070	— 8	+1.6	+.4	40 37 43.23	— 1 20.22	— 5	+	30	— 3	23.23	—3	53.4		
			13.6880	28.1683	+ 78	+.8	— .7	40 42 30.08	— 6 5.93	— 49	+	4	—10	23.60	+9	63.4		
			17.6790	22.6600	+ 6	+1.8	+.6	40 34 17.22	+ 2 5.81	+	25	+	36	+ 3	23.67	+9		
			22.4157	19.1440	+ 17	—2.1	— .7	40 35 0.51	+ 1 22.68	+	18	— 42	+ 3	22.98	+9	63.0		
					27.8283	13.3567	+ 51	0	—1.6	40 42 30.21	— 6 5.66	— 48	— 20	—11	23.76	—2		
					7.1870 ¹¹	30.7507 ^{1v}	— 21	— .4	—3.2	40 26 27.99	+ 9 55.12	+1.39	— 47	+19	24.22	—2		
	20.1233	21.2033			+ 5	— .7	+1.2	40 36 50.13	— 27.29	+	9	+	4	— 1	22.96	—2	54.3	
Oct. 3			27.4310	12.5593	0	— .2	— .8	40 42 39.22	— 6 15.62	— 48	— 13	—12	22.87	—3	53.6			
			22.7840	18.2580	+ 17	+.1	+.3	40 34 28.49	+ 1 54.36	+	25	+	6	+ 4	23.20	—3		
			27.7390	13.8967	+ 66	+4.6	+3.3	40 42 13.93	— 5 49.80	— 46	+1.14	— 9	24.72	—3	53.2			
	I 10 R		18.0300	21.2070	— 8	+1.6	+.4	40 37 43.23	— 1 20.22	— 5	+	30	— 3	23.23	—3	53.4		
			13.6880	28.1683	+ 78	+.8	— .7	40 42 30.08	— 6 5.93	— 49	+	4	—10	23.60	+9	63.4		
			17.6790	22.6600	+ 6	+1.8	+.6	40 34 17.22	+ 2 5.81	+	25	+	36	+ 3	23.67	+9		
			22.4157	19.1440	+ 17	—2.1	— .7	40 35 0.51	+ 1 22.68	+	18	— 42	+ 3	22.98	+9	63.0		
					27.8283	13.3567	+ 51	0	—1.6	40 42 30.21	— 6 5.66	— 48	— 20	—11	23.76	—2		
					7.1870 ¹¹	30.7507 ^{1v}	— 21	— .4	—3.2	40 26 27.99	+ 9 55.12	+1.39	— 47	+19	24.22	—2		
	20.1233	21.2033			+ 5	— .7	+1.2	40 36 50.13	— 27.29	+	9	+	4	— 1	22.96	—2	54.3	
Oct. 3			27.4310	12.5593	0	— .2	— .8	40 42 39.22	— 6 15.62	— 48	— 13	—12	22.87	—3	53.6			
			22.7840	18.2580	+ 17	+.1	+.3	40 34 28.49	+ 1 54.36	+	25	+	6	+ 4	23.20	—3		
			27.7390	13.8967	+ 66	+4.6	+3.3	40 42 13.93	— 5 49.80	— 46	+1.14	— 9	24.72	—3	53.2			
	I 10 R		18.0300	21.2070	— 8	+1.6	+.4	40 37 43.23	— 1 20.22	— 5	+	30	— 3	23.23	—3	53.4		
			13.6880	28.1683	+ 78	+.8	— .7	40 42 30.08	— 6 5.93	— 49	+	4	—10	23.60	+9	63.4		
			17.6790	22.6600	+ 6	+1.8	+.6	40 34 17.22	+ 2 5.81	+	25	+	36	+ 3	23.67	+9		
			22.4157	19.1440	+ 17	—2.1	— .7	40 35 0.51	+ 1 22.68	+	18	— 42	+ 3	22.98	+9	63.0		
					27.8283	13.3567	+ 51	0	—1.6	40 42 30.21	— 6 5.66	— 48	— 20	—11	23.76	—2		
					7.1870 ¹¹	30.7507 ^{1v}	— 21	— .4	—3.2	40 26 27.99	+ 9 55.12	+1.39	— 47	+19	24.22	—2		
	20.1233	21.2033			+ 5	— .7	+1.2	40 36 50.13	— 27.29	+	9	+	4	— 1	22.96	—2	54.3	
Oct. 3			27.4310	12.5593	0	— .2	— .8	40 42 39.22	— 6 15.62	— 48	— 13	—12	22.87	—3	53.6			
			22.7840	18.2580	+ 17	+.1	+.3	40 34 28.49	+ 1 54.36	+	25	+	6	+ 4	23.20	—3		
			27.7390	13.8967	+ 66	+4.6	+3.3	40 42 13.93	— 5 49.80	— 46	+1.14	— 9	24.72	—3	53.2			
	I 10 R		18.0300	21.2070	— 8	+1.6	+.4	40 37 43.23	— 1 20.22	— 5	+	30	— 3	23.23	—3	53.4		
			13.6880	28.1683	+ 78	+.8	— .7	40 42 30.08	— 6 5.93	— 49	+	4	—10	23.60	+9	63.4		
			17.6790	22.6600	+ 6	+1.8	+.6	40 34 17.22	+ 2 5.81	+	25	+	36	+ 3	23.67	+9		
			22.4157	19.1440	+ 17	—2.1	— .7	40 35 0.51	+ 1 22.68	+	18	— 42	+ 3	22.98	+9	63.0		
					27.8283	13.3567	+ 51	0	—1.6	40 42 30.21	— 6 5.66	— 48	— 20	—11	23.76	—2		

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Oct. 3	I	5 R	24.6127	20.1453	+ 63	— .3	+1.3	40 34 29.58	+ 1 52.99	+ 23	+ 12	+ 3	40 36 22.95	+ 9	
		6	22.2110	21.8313	+ 6	+ .3	0	40 36 13.47	+ 9.61	+ 10	+ 4	0	23.22	+ 8	
		7	11.4213	29.8497	+ 66	— .7	— .3	40 28 36.85	+ 7 45.60	+ 77	— 15	+15	22.72	+ 8	61.8
		8	8.6450 ⁱⁱ	32.0200 ^{iv}	+ 8	— .2	+ .1	40 26 31.46	+ 9 50.40	+1.37	— 2	+17	23.38	+ 9	
		9	13.7223	25.2647	— 34	0	— .2	40 31 31.21	+ 4 51.43	+ 50	+ 2	+ 8	23.24	+ 8	
		10	27.6830	16.0693	+129	+ .5	— .2	40 41 17.48	— 4 53.64	— 31	+ 5	—13	23.45	+ 7	60.9
	II	1	22.2283	23.5767	+ 25	— .4	— .5	40 36 57.32	— 34.12	+ 8	— 12	— 1	23.15	+ 7	60.6
Oct. 7		2	23.1480	22.3307	+ 11	+ .2	+ .9	40 36 43.58	— 20.67	+ 7	+ 14	— 1	23.11	+ 7	60.4
	V	1 R	28.4850	12.6400	+ 53	— .9	—1.2	40 29 42.47	+ 6 40.35	+ 66	— 30	+11	23.29	— 2	52.9a
		2	18.6653	23.3290	+ 28	— .5	—1.1	40 38 20.83	— 1 57.86	— 11	— 22	— 3	22.61	— 2	53.4
		3	9.1177 ⁱⁱ	32.6803 ^{iv}	+ 19	—2.0	—2.1	40 26 27.73	+ 9 55.20	+1.44	— 58	+24	24.03	— 2	d
		4	13.1767	27.7207	+ 38	— .8	+ .4	40 42 30.79	— 6 7.45	— 48	— 8	—11	22.67	— 2	
		5	31.7597 ^{iv}	8.2633 ⁱⁱ	0	— .4	+ .7	40 26 28.50	+ 9 53.48	+1.39	+ 3	+19	23.59	— 2	52.5
		6	22.3347	21.2527	+ 11	— .3	— .6	40 36 50.53	— 27.36	+ 9	— 12	— 1	23.13	— 2	
		7	13.2953	28.1710	+ 65	— .4	+ .1	40 42 39.59	— 6 15.90	— 48	— 4	—12	23.05	— 2	
		8	19.4567	23.9543	+ 45	— .9	— .1	40 34 28.79	+ 1 53.71	+ 25	— 16	+ 4	22.63	— 3	52.1
		9	13.1893	27.1000	+ 11	+ .9	+ .9	40 42 14.25	— 5 51.39	— 47	+ 26	— 9	22.56	— 3	
Oct. 8		10	21.8177	18.6230	+ 4	+1.5	+ .9	40 37 43.42	— 1 20.71	— 5	+ 34	— 3	22.97	— 3	51.6
	V	1 D	12.8740	28.6917	+ 73	—1.2	— .1	40 29 42.58	+ 6 39.71	+ 66	— 20	+11	22.86	— 1	53.4
		2	23.3067	18.6350	+ 27	+1.5	+ .2	40 38 20.94	— 1 58.06	— 12	+ 26	— 3	22.99	— 2	53.4
		3	31.1033 ^{iv}	7.6137 ⁱⁱ	— 16	+1.8	+2.5	40 26 27.80	+ 9 53.39	+1.44	+ 60	+24	23.47	— 2	
		4	26.8397	12.2850	— 38	+ .6	+1.0	40 42 30.87	— 6 7.53	— 48	+ 22	—11	22.97	— 2	
		5	7.8857 ⁱⁱ	31.3997 ^{iv}	— 9	+2.1	— .5	40 26 28.57	+ 9 53.39	+1.39	+ 26	+19	24.30	— 2	52.6
		6	19.3413	20.4400	0	—2.1	—1.7	40 36 50.57	— 27.75	+ 9	— 54	— 1	22.36	— 2	
		7	27.5937	12.7240	+ 14	— .2	— .1	40 42 39.63	— 6 15.62	— 48	— 4	—12	23.37	— 2	52.2
		8	22.4077	17.8923	+ 5	+1.2	+ .6	40 34 28.81	+ 1 54.06	+ 25	+ 26	+ 4	23.42	— 3	
		9	27.8377	13.9630	+ 75	+1.1	+ .4	40 42 14.21	— 5 50.64	— 47	+ 22	— 9	23.23	— 3	
Oct. 9		10	18.4143	21.5883	0	— .8	—2.1	40 37 43.43	— 1 20.17	— 5	— 40	— 3	22.78	— 3	52.6
	V	1 R	27.0853	11.2560	— 76	—1.0	0	40 29 42.69	+ 6 39.62	+ 66	— 16	+11	22.92	— 1	56.4
		2	16.9980	21.6643	— 20	0	—1.1	40 38 21.02	— 1 57.81	— 12	— 14	— 3	22.92	— 2	56.0
		3	8.9967 ⁱⁱ	32.4863 ^{iv}	+ 16	+1.5	+1.1	40 26 27.86	+ 9 53.34	+1.44	+ 37	+24	23.25	— 2	
		4	12.0800	26.6623	— 52	+2.0	+2.7	40 42 30.94	— 6 8.18	— 48	+ 66	—11	22.83	— 2	55.4
		5	31.8633 ^{iv}	8.3713 ⁱⁱ	+ 3	—1.0	— .4	40 26 28.63	+ 9 53.37	+1.39	— 20	+19	23.38	— 2	55.5
		6	21.0467	19.9697	+ 3	+ .5	+ .5	40 36 50.60	— 27.21	+ 9	+ 14	— 1	23.61	— 2	55.1
		7	12.4847	27.3743	— 5	+2.0	+1.0	40 42 39.66	— 6 16.06	— 48	+ 44	—12	23.44	— 2	
		8	17.6500	22.1577	— 3	— .4	— .9	40 34 28.82	+ 1 53.85	+ 25	— 18	+ 4	22.78	— 3	55.0
		9	14.3737	28.2497	+108	—1.5	0	40 42 14.22	— 5 50.75	— 47	— 23	— 9	22.68	— 3	
		10	21.7737	18.6290	+ 6	—2.4	—3.2	40 37 43.43	— 1 19.44	— 5	— 78	— 3	23.13	— 3	54.1
Oct. 14		2 D	27.9567	13.4337	+ 59	+2.0	+ .4	40 42 30.34	— 6 6.97	— 49	+ 36	—10	23.14	+ 9	59.6
	I	3	22.8003	17.8390	+ 10	— 9	— .6	40 34 17.66	+ 2 5.34	+ 25	— 22	+ 3	23.06	+ 9	
		4	17.8117	21.0410	— 12	+1.6	0	40 35 1.12	+ 1 21.53	+ 18	+ 25	+ 3	23.11	+ 9	59.4
		5	18.7097	23.1583	+ 28	+1.3	+2.2	40 34 30.33	+ 1 52.43	+ 23	+ 48	+ 3	23.50	+ 9	
		6	21.8047	22.1613	+ 5	— .3	— .6	40 36 14.26	+ 9.02	+ 10	— 12	0	23.26	+ 8	
		7	29.6063	11.2267	+ 45	— .2	—1.0	40 28 37.34	+ 7 44.34	+ 77	— 16	+15	22.44	+ 9	59.0
		8	32.0773 ^{iv}	8.7320 ⁱⁱ	+ 10	— .7	—1.0	40 26 32.59	+ 9 49.66	+1.36	— 24	+17	23.54	+ 9	58.6
		9	25.6797	14.1827	— 4	—1.9	— .4	40 31 32.47	+ 4 50.37	+ 50	— 34	+ 8	23.08	+ 9	58.6
		10	14.1163	25.8267	— 3	+1.4	+ .9	40 41 18.73	— 4 55.76	— 31	+ 33	—13	22.86	+ 7	58.1
		1	20.5933	19.1930	0	— .2	— .5	40 36 58.67	— 35.37	+ 8	— 10	— 1	23.27	+ 7	
		2	19.4533	20.2997	0	—1.8	—1.4	40 36 45.07	— 21.38	+ 7	— 46	— 1	23.29	+ 7	
		3	11.0983	27.7523	— 56	0	— .7	40 29 22.24	+ 7 0.49	+ 70	— 9	+13	23.47	+ 8	57.4
		5	10.9437 ⁱⁱ	28.1180 ^{iv}	+ 10	—1.0	—1.9	40 29 8.98	+ 7 13.68	+1.13	— 40	+12	23.51	+ 8	
		6	30.7927 ^{iv}	11.1880 ⁱⁱ	0	—3.3	—2.7	40 28 7.25	+ 8 15.16	+1.21	— 86	+14	22.90	+ 8	
		7	12.9127 ⁱⁱ	28.1373 ^{iv}	— 14	— .8	— .9	40 29 57.60	+ 6 24.49	+1.05	— 24	+11	23.01	+ 7	
		8	26.4313	10.6807	—136	— .9	—1.9	40 43 1.95	— 6 37.47	— 53	— 38	—11	23.46	+ 7	56.6
		9	18.8117	21.8350	+ 8	—1.1	0	40 37 39.47	— 1 16.38	+ 1	— 17	— 2	22.91	+ 6	56.5

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Oct. 17	I	R	13.4967	28.0070	+ 64	+1.2	+2.2	40 42 30.31	- 6 6.68	- 49	+ 46	-10	40 36 23.50	+9	52.4b
			18.9687	23.9530	+ 44	-1.9	-1.8	40 34 17.67	+ 2 6.01	+ 25	- 52	+ 3	23.44	+9	
			21.8527	18.6310	+ 7	+ .7	+ .6	40 35 1.20	+ 1 21.40	+ 18	+ 18	+ 3	22.99	+9	52.0
			22.4137	17.9613	+ 7	+ .7	+ .9	40 34 30.45	+ 1 52.48	+ 23	+ 22	+ 3	23.41	+9	51.6
			22.5747	22.2427	+ 6	+1.0	+2.4	40 36 14.42	+ 8.40	+ 10	+ 46	0	23.38	+8	51.1
	II		11.5837	29.9613	+ 84	+2.0	+1.1	40 28 37.56	+ 7 44.40	+ 77	+ 45	+15	23.33	+9	
			9.0873 ⁱⁱ	32.4060 ^{iv}	+ 17	+2.2	+ .2	40 26 32.84	+ 9 49.05	+1.36	+ 36	+17	23.78	+9	
			13.5383	25.0120	- 49	+2.0	+2.3	40 31 32.76	+ 4 49.69	+ 49	+ 60	+ 8	23.62	+9	50.6
			14.4843	26.1670	+ 22	- .3	- .6	40 41 19.05	- 4 55.15	- 31	- 12	-13	23.34	+7	50.4
			21.9930	23.4127	+ 25	+ .2	+ .2	40 36 59.03	- 35.92	+ 8	+ 6	- 1	23.24	+7	
Oct. 18	I		22.9007	22.0283	+ 15	+1.0	- .8	40 36 45.47	- 22.07	+ 7	+ 6	- 1	23.52	+7	
			29.0703	12.4437	+ 73	-1.8	- .9	40 29 22.69	+ 7 0.16	+ 70	- 40	+13	23.28	+8	
			19.4110	24.3160	+ 53	- .9	- .5	40 38 27.58	- 2 4.03	- 9	- 20	- 4	23.22	+7	49.8
			29.7423 ^{iv}	12.6263 ⁱⁱ	- 20	- .9	- .2	40 29 9.52	+ 7 12.27	+1.13	- 16	+12	22.88	+8	
			10.2313 ⁱⁱ	29.7807 ^{iv}	0	+ .9	+1.0	40 28 7.83	+ 8 13.79	+1.20	+ 26	+14	23.22	+8	48.0
	II		27.6753 ^{iv}	12.5033 ⁱⁱ	- 5	+2.2	+1.6	40 29 58.20	+ 6 23.09	+1.05	+ 54	+11	22.99	+7	48.4
			12.2777	28.0337	+ 14	-2.3	- .8	40 43 2.56	- 6 38.02	- 53	- 46	-11	23.44	+7	48.5
			21.8670	18.8457	+ 8	-1.5	- .5	40 37 39.76	- 1 16.34	+ 1	- 30	- 2	23.11	+6	47.6
			27.9377	13.4463	+ 60	- .2	- .6	40 42 30.26	- 6 6.18	- 49	- 10	-10	23.39	+9	54.1
			17.7577	20.9983	- 15	+1.5	+ .4	40 35 1.15	+ 1 21.81	+ 18	+ 28	+ 3	23.45	+9	
Oct. 20	I		17.3407	21.7963	- 13	+1.0	+ .7	40 34 30.46	+ 1 52.50	+ 23	+ 24	+ 3	23.46	+9	
			19.7720	20.1093	0	0	- .5	40 36 14.44	+ 8.52	+ 10	- 6	0	23.00	+8	53.6
			30.2797	11.9117	+120	-1.1	-1.1	40 28 37.59	+ 7 44.24	+ 77	- 31	+15	22.44	+9	
			31.8133 ^{iv}	8.5047 ⁱⁱ	+ 3	- .7	0	40 26 32.88	+ 9 48.74	+1.36	- 11	+17	23.04	+9	
			26.6117	15.1490	+ 60	+ .4	+ .1	40 31 32.82	+ 4 49.68	+ 49	+ 8	+ 8	23.15	+9	53.9
	II		13.4117	25.1313	- 50	- .6	- .1	40 41 19.11	- 4 55.89	- 31	- 11	-13	22.67	+7	53.4
			20.3917	18.9550	- 2	+2.6	+1.7	40 36 59.11	- 36.29	+ 8	+ 62	- 1	23.51	+7	
			19.1870	20.0900	- 4	-1.9	- .3	40 36 45.54	- 22.80	+ 7	- 34	- 1	22.46	+7	
			11.1253	27.7363	- 55	+1.8	0	40 29 22.81	+ 6 59.42	+ 70	+ 28	+13	23.34	+8	54.6
			21.7217	16.7680	- 22	+1.4	+ .2	40 38 27.70	- 2 5.06	- 9	+ 24	- 4	22.75	+7	54.9
Oct. 21	I	R	10.7453 ⁱⁱ	27.8363 ^{iv}	+ 13	+1.9	+1.2	40 29 9.67	+ 7 11.72	+1.13	+ 45	+12	23.09	+8	
			31.0127 ^{iv}	11.4613 ⁱⁱ	- 4	- .2	- .3	40 28 7.99	+ 8 13.82	+1.21	- 7	+14	23.09	+8	
			13.0967 ⁱⁱ	28.2642 ^{iv}	- 22	+1.9	+ .9	40 29 58.37	+ 6 23.04	+1.04	+ 41	+11	22.97	+7	54.1
			28.0330	12.2523	+ 12	+ .6	+ .1	40 43 2.71	- 6 38.62	- 53	+ 11	-11	23.56	+7	
			18.5350	21.6117	0	+ .8	+1.6	40 37 40.23	- 1 17.71	0	+ 33	- 2	22.83	+6	53.6
	II		12.2267	26.7233	- 47	0	+ .5	40 42 30.14	- 6 6.04	- 49	+ 6	-10	23.57	+9	
			17.7050	22.6793	+ 7	+ .4	- .3	40 34 17.56	+ 2 5.66	+ 25	+ 2	+ 3	23.52	+9	
			22.3930	19.1287	+ 15	- .8	- .8	40 35 1.12	+ 1 22.49	- 6	- 22	+ 3	23.36	+9	52.5
			22.7107	18.2690	+ 13	+ .2	+ .6	40 34 30.43	+ 1 52.22	+ 23	+ 10	+ 3	23.01	+9	
			21.5383	21.2030	+ 3	+ .3	+ .4	40 36 14.44	+ 8.48	+ 10	+ 10	0	23.12	+8	52.6
Oct. 24	I	D	11.8260	30.1970	+109	+1.8	+ .3	40 28 37.62	+ 7 44.30	+ 77	+ 32	+15	23.16	+9	52.0
			28.2833	13.8010	+ 90	+ .2	- .6	40 42 30.08	- 6 6.03	- 49	- 4	-10	23.42	+9	53.7
			22.7403	17.7753	+ 9	- .3	0	40 34 17.53	+ 2 5.43	+ 25	- 4	+ 3	23.20	+9	54.0
			18.2897	21.5270	- 2	+ .2	+ .7	40 35 1.11	+ 1 21.76	+ 18	+ 12	+ 3	23.20	+9	
			17.4447	21.8910	- 9	+1.4	+2.3	40 34 30.42	+ 1 52.28	+ 23	+ 51	+ 3	23.47	+9	53.1
	II	R	18.9333	19.2640	0	+ .5	+ .6	40 36 14.43	+ 8.35	+ 10	+ 15	0	23.03	+8	
			13.2623	27.7457	+ 41	- .2	+ .4	40 42 29.95	- 6 5.90	- 49	+ 2	-10	23.48	+9	64.4
			17.8760	22.8523	+ 13	+ .1	+ .1	40 34 17.43	+ 2 5.71	+ 25	+ 3	+ 3	23.45	+9	
			22.8117	19.5717	+ 22	+ .4	+ .1	40 35 1.05	+ 1 21.89	+ 18	+ 8	+ 3	23.23	+9	64.0
			24.0437	19.6010	+ 46	+ .6	+1.8	40 34 30.41	+ 1 52.33	+ 23	+ 32	+ 3	23.32	+9	
Oct. 24			21.1747	20.8457	0	+ .8	+1.2	40 36 14.46	+ 8.31	+ 10	+ 28	0	23.15	+8	
			30.0963	11.7543	+100	+1.5	+2.0	40 28 37.70	+ 7 43.51	+ 76	+ 48	+15	22.60	+9	
			32.4210 ^{iv}	9.1257 ⁱⁱ	+ 15	+ .8	+ .7	40 26 33.05	+ 9 48.39	+1.36	+ 22	+17	23.19	+9	62.9
			25.6243	14.1703	- 8	+ .4	+1.2	40 31 33.05	+ 4 49.26	+ 49	+ 22	+ 8	23.10	+9	
			25.9963	14.2800	+ 8	+1.7	+ .3	40 41 19.39	- 4 55.93	- 31	+ 30	-13	23.32	+7	63.3

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.	
						A	B		Micrometer	δ	l	r				
Oct. 24	II	1 R	20.6450	22.0867	+ 13	-1.3	-.6	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 59.48 \end{smallmatrix}$	- 36.45	+ 8	- 28	- 1	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.82 \end{smallmatrix}$	+ 7	63.4	
			21.5467	20.6293	+ 5	+ .6	+2.6	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 46.00 \end{smallmatrix}$	- 23.19	+ 6	+ 42	- 1	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.28 \end{smallmatrix}$	+ 7		
			30.0150	13.4540	+168	-1.5	-1.1	$\begin{smallmatrix} \circ & / & // \\ 40 & 29 & 23.36 \end{smallmatrix}$	+ 6 58.70	+ 70	- 37	+13	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.52 \end{smallmatrix}$	+ 8	63.2	
			19.0127	23.9760	+ 44	+ .8	+1.0	$\begin{smallmatrix} \circ & / & // \\ 40 & 38 & 28.28 \end{smallmatrix}$	- 2 5.46	- 9	+ 25	- 4	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.94 \end{smallmatrix}$	+ 7		
			29.5087 ^{iv}	12.4333 ⁱⁱ	+ 96	-.2	+ .2	$\begin{smallmatrix} \circ & / & // \\ 40 & 29 & 10.36 \end{smallmatrix}$	+ 7 11.38	+1.13	0	+12	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.99 \end{smallmatrix}$	+ 8		
Oct. 25	VI	1 D	6	10.3780 ⁱⁱ	29.8870 ^{iv}	0	+2.0	+1.8	$\begin{smallmatrix} \circ & / & // \\ 40 & 23 & 8.75 \end{smallmatrix}$	+ 8 12.73	+1.22	+ 54	+14	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.38 \end{smallmatrix}$	+ 8	63.6
			28.3593 ^{iv}	13.1997 ⁱⁱ	- 24	0	-.2	$\begin{smallmatrix} \circ & / & // \\ 40 & 29 & 59.17 \end{smallmatrix}$	+ 6 22.82	+1.05	- 2	+11	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.13 \end{smallmatrix}$	+ 8		
			12.1637	27.9873	+ 7	-.3	-1.1	$\begin{smallmatrix} \circ & / & // \\ 40 & 43 & 3.57 \end{smallmatrix}$	- 6 39.67	- 53	- 18	-11	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.08 \end{smallmatrix}$	+ 7		
			22.6777	19.6140	+ 20	-1.2	-.7	$\begin{smallmatrix} \circ & / & // \\ 40 & 37 & 41.02 \end{smallmatrix}$	- 1 17.43	0	- 28	- 2	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.29 \end{smallmatrix}$	+ 6	62.6	
			15.3373	23.9877	- 18	-2.7	-2.5	$\begin{smallmatrix} \circ & / & // \\ 40 & 32 & 45.19 \end{smallmatrix}$	+ 3 38.47	+ 44	- 74	+ 7	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.43 \end{smallmatrix}$	- 3	41.16	
			2	24.6123	17.5397	+ 44	-7.7	-6.2	$\begin{smallmatrix} \circ & / & // \\ 40 & 33 & 25.69 \end{smallmatrix}$	+ 2 58.76	+ 36	-1.98	+ 5	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.88 \end{smallmatrix}$	- 3	
			28.0593	12.1757	+ 9	+2.7	+ .7	$\begin{smallmatrix} \circ & / & // \\ 40 & 43 & 5.48 \end{smallmatrix}$	- 6 41.25	- 61	+ 51	-12	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 24.01 \end{smallmatrix}$	- 3		
			24.0150	17.4547	+ 29	-1.4	-1.6	$\begin{smallmatrix} \circ & / & // \\ 40 & 33 & 37.06 \end{smallmatrix}$	+ 2 45.78	+ 34	- 42	+ 5	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.81 \end{smallmatrix}$	- 3	41.1	
			23.0350	17.8540	+ 15	-.8	-.9	$\begin{smallmatrix} \circ & / & // \\ 40 & 38 & 33.85 \end{smallmatrix}$	- 2 10.91	- 15	- 1	- 4	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.74 \end{smallmatrix}$	- 3	41.5	
			9.3443 ⁱⁱ	30.9197 ^{iv}	0	-.7	-1.1	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 16.92 \end{smallmatrix}$	+ 9 5.01	+1.37	- 25	+20	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.25 \end{smallmatrix}$	- 3		
			7	21.1510	19.0450	0	-1.4	-1.2	$\begin{smallmatrix} \circ & / & // \\ 40 & 37 & 16.60 \end{smallmatrix}$	- 53.20	- 3	- 37	- 2	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.98 \end{smallmatrix}$	- 4	
8	12.8600	28.7753	+ 78	-.6	+ .1	$\begin{smallmatrix} \circ & / & // \\ 40 & 43 & 5.69 \end{smallmatrix}$	- 6 42.22	- 61	- 8	-12	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.66 \end{smallmatrix}$	- 4	41.0			
9	29.6893 ^{iv}	9.4517 ⁱⁱ	0	+ .5	+2.0	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 50.08 \end{smallmatrix}$	+ 8 31.21	+1.29	+ 33	+16	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.07 \end{smallmatrix}$	- 4				
10	22.9293	16.5500	- 10	-3.9	-1.5	$\begin{smallmatrix} \circ & / & // \\ 40 & 33 & 42.19 \end{smallmatrix}$	+ 2 41.11	+ 33	- 80	+ 5	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.88 \end{smallmatrix}$	- 4	40.9			
11	14.4380	27.5157	+ 74	-.6	+ .3	$\begin{smallmatrix} \circ & / & // \\ 40 & 30 & 51.72 \end{smallmatrix}$	+ 5 30.54	+ 63	- 6	+10	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.93 \end{smallmatrix}$	- 4				
Oct. 28	VI	1 R	12	30.0793	8.1223	-117	-3.0	-1.7	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 7.92 \end{smallmatrix}$	+ 9 14.35	+1.01	- 68	+18	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.78 \end{smallmatrix}$	- 4	41.6
			25.8567	17.2277	+ 77	+ .5	0	$\begin{smallmatrix} \circ & / & // \\ 40 & 32 & 45.14 \end{smallmatrix}$	+ 3 38.16	+ 44	+ 8	+ 7	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.89 \end{smallmatrix}$	- 3	43.4	
			16.9347	23.9593	+ 18	+ .9	-.5	$\begin{smallmatrix} \circ & / & // \\ 40 & 33 & 25.63 \end{smallmatrix}$	+ 2 57.48	+ 36	+ 8	+ 5	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.60 \end{smallmatrix}$	- 3		
			13.0497	28.9240	+ 91	+ .7	+ .2	$\begin{smallmatrix} \circ & / & // \\ 40 & 43 & 5.39 \end{smallmatrix}$	- 6 41.22	- 61	+ 14	-12	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.58 \end{smallmatrix}$	- 3	42.9	
			17.6763	24.2767	+ 39	-.2	-.3	$\begin{smallmatrix} \circ & / & // \\ 40 & 33 & 36.88 \end{smallmatrix}$	+ 2 46.82	+ 34	- 7	+ 5	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 24.02 \end{smallmatrix}$	- 3		
			5	17.4317	22.5917	0	+ .6	+1.3	$\begin{smallmatrix} \circ & / & // \\ 40 & 38 & 33.65 \end{smallmatrix}$	- 2 10.84	- 15	+ 26	- 4	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.88 \end{smallmatrix}$	- 3	43.4
			32.0150 ^{iv}	10.4247 ⁱⁱ	+ 11	+1.9	+1.1	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 16.68 \end{smallmatrix}$	+ 9 5.38	+1.37	+ 44	+20	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 24.07 \end{smallmatrix}$	- 3		
			19.5593	21.6427	+ 8	-2.2	-1.1	$\begin{smallmatrix} \circ & / & // \\ 40 & 37 & 16.32 \end{smallmatrix}$	- 52.65	- 3	- 48	- 2	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.14 \end{smallmatrix}$	- 4		
			28.7170	12.8487	+ 75	-.8	-1.3	$\begin{smallmatrix} \circ & / & // \\ 40 & 43 & 5.37 \end{smallmatrix}$	- 6 41.03	- 60	- 29	-12	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.33 \end{smallmatrix}$	- 4	42.9	
			11.1590 ⁱⁱ	31.4497 ^{iv}	0	-1.2	-1.4	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 49.85 \end{smallmatrix}$	+ 8 32.55	+1.24	- 36	+16	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.44 \end{smallmatrix}$	- 4		
Oct. 29	VI	1 D	10	16.9313	23.3357	+ 5	+1.1	+1.0	$\begin{smallmatrix} \circ & / & // \\ 40 & 33 & 41.75 \end{smallmatrix}$	+ 2 41.79	+ 33	+ 30	+ 5	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 24.22 \end{smallmatrix}$	- 4	43.1
			15.8880	24.5253	+ 11	-.8	-3.2	$\begin{smallmatrix} \circ & / & // \\ 40 & 32 & 45.17 \end{smallmatrix}$	+ 3 38.21	+ 44	- 54	+ 7	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.35 \end{smallmatrix}$	- 3	36.4	
			24.6057	17.5903	+ 45	-2.6	-1.3	$\begin{smallmatrix} \circ & / & // \\ 40 & 33 & 25.65 \end{smallmatrix}$	+ 2 57.33	+ 36	- 57	+ 5	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.82 \end{smallmatrix}$	- 3		
			28.7960	12.9423	+ 82	-1.7	+1.3	$\begin{smallmatrix} \circ & / & // \\ 40 & 43 & 5.39 \end{smallmatrix}$	- 6 40.69	- 60	- 10	-12	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.88 \end{smallmatrix}$	- 3	37.2	
			23.6700	17.1027	+ 16	-2.8	-.6	$\begin{smallmatrix} \circ & / & // \\ 40 & 33 & 36.86 \end{smallmatrix}$	+ 2 45.94	+ 34	- 51	+ 5	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.68 \end{smallmatrix}$	- 3		
			5	23.1203	17.9777	+ 17	+ .3	-.5	$\begin{smallmatrix} \circ & / & // \\ 40 & 38 & 33.61 \end{smallmatrix}$	- 2 9.95	- 15	- 2	- 4	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.45 \end{smallmatrix}$	- 3	a
			8.5807 ⁱⁱ	30.1623 ^{iv}	- 5	+ .2	+ .5	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 16.63 \end{smallmatrix}$	+ 9 5.16	+1.26	+ 10	+20	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.35 \end{smallmatrix}$	- 3		
			21.5050	19.4090	+ 5	+ .9	-.1	$\begin{smallmatrix} \circ & / & // \\ 40 & 37 & 16.26 \end{smallmatrix}$	- 52.96	- 3	+ 12	- 2	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.37 \end{smallmatrix}$	- 4		
			12.1040	28.0007	+ 4	-1.7	+ .1	$\begin{smallmatrix} \circ & / & // \\ 40 & 43 & 5.29 \end{smallmatrix}$	- 6 41.58	- 60	- 25	-12	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.74 \end{smallmatrix}$	- 4	36.6	
			31.0477 ^{iv}	10.7830 ⁱⁱ	0	+ .3	+ .7	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 49.65 \end{smallmatrix}$	+ 8 31.91	+1.18	+ 14	+16	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.04 \end{smallmatrix}$	- 4	36.4	
Oct. 30	VI	1 R	10	23.3303	16.9493	+ 5	+ .2	+ .1	$\begin{smallmatrix} \circ & / & // \\ 40 & 33 & 41.63 \end{smallmatrix}$	+ 2 41.19	+ 33	+ 4	+ 5	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.24 \end{smallmatrix}$	- 4	36.5
			12.8850	26.0197	- 43	+1.5	+ .4	$\begin{smallmatrix} \circ & / & // \\ 40 & 30 & 51.13 \end{smallmatrix}$	+ 5 31.69	+ 63	+ 28	+10	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.83 \end{smallmatrix}$	- 4		
			30.2763	8.3077	- 90	-1.6	+ .7	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 7.25 \end{smallmatrix}$	+ 9 14.72	+1.01	- 16	+18	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.00 \end{smallmatrix}$	- 4	36.4	
			25.2563	16.6133	+ 48	-1.1	-.1	$\begin{smallmatrix} \circ & / & // \\ 40 & 32 & 45.22 \end{smallmatrix}$	+ 3 38.46	+ 44	- 18	+ 7	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 24.01 \end{smallmatrix}$	- 3	31.4	
			16.1147	23.0953	- 17	+2.4	+3.4	$\begin{smallmatrix} \circ & / & // \\ 40 & 33 & 25.68 \end{smallmatrix}$	+ 2 56.30	+ 36	+ 80	+ 5	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.19 \end{smallmatrix}$	- 3	b	
			3	12.9173	28.7980	+ 81	+1.8	-.9	$\begin{smallmatrix} \circ & / & // \\ 40 & 43 & 5.42 \end{smallmatrix}$	- 6 41.39	- 60	+ 16	-12	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.47 \end{smallmatrix}$	- 3	
			17.9713	24.5500	+ 48	+ .9	+2.0	$\begin{smallmatrix} \circ & / & // \\ 40 & 33 & 36.86 \end{smallmatrix}$	+ 2 46.32	+ 34	+ 40	+ 5	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.97 \end{smallmatrix}$	- 3	31.5	
			17.9310	23.0653	+ 15	-2.0	-.9	$\begin{smallmatrix} \circ & / & // \\ 40 & 38 & 33.60 \end{smallmatrix}$	- 2 9.74	- 15	- 42	- 4	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.25 \end{smallmatrix}$	- 3		
			31.4273 ^{iv}	9.8267 ⁱⁱ	+ 5	0	+ .5	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 16.60 \end{smallmatrix}$	+ 9 5.70	+1.26	+ 6	+20	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.82 \end{smallmatrix}$	- 3		
			19.4680	21.5847	+ 8	+ .7	-.2	$\begin{smallmatrix} \circ & / & // \\ 40 & 37 & 16.21 \end{smallmatrix}$	- 53.50	- 3	+ 8	- 2	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 22.74 \end{smallmatrix}$	- 4		
			8	27.9240	12.0860	0	-.7	-1.0	$\begin{smallmatrix} \circ & / & // \\ 40 & 43 & 5.23 \end{smallmatrix}$	- 6 40.10	- 60	- 24	-12	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 24.17 \end{smallmatrix}$	- 4	31.5
			9	10.6640 ⁱⁱ	30.9510 ^{iv}	0	0	+ .1	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 49.57 \end{smallmatrix}$	+ 8 32.49	+1.18	- 2	+ 5	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.42 \end{smallmatrix}$	- 4	31.0
18.6797	25.0197	+ 72	+4.4	+4.6	$\begin{smallmatrix} \circ & / & // \\ 40 & 33 & 41.53 \end{smallmatrix}$	+ 2 40.35	+ 33	+1.31	+ 16	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.57 \end{smallmatrix}$	- 4	31.4				
27.3030	14.1927	+ 58	+1.6	+3.2	$\begin{smallmatrix} \circ & / & // \\ 40 & 30 & 51.02 \end{smallmatrix}$	+ 5 31.34	+ 63	+ 68	+10	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 23.77 \end{smallmatrix}$	- 4					
12	9.4387	31.4597	+ 53	-2.4	-1.9	$\begin{smallmatrix} \circ & / & // \\ 40 & 27 & 7.12 \end{smallmatrix}$	+ 9 16.44	+1.02	- 63	+18	$\begin{smallmatrix} \circ & / & // \\ 40 & 36 & 24.13 \end{smallmatrix}$	- 4	31.0			

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude			Δ	Ther.
						A	B		Micrometer	δ	l	r					
Oct. 31	II	1 D	20.5410	19.0810	0	+2.0	+ .2	40 37 0.12	— 36.88	+ 7	+ 34	— 1	40 36 23.64	+7	38.0		
			20.1450	21.0903	+ 5	0	— .2	40 36 46.72	— 23.89	+ 6	— 2	— 1	22.86	+8			
			11.6427	28.1897	— 9	+1.9	+2.0	40 29 24.20	+ 6 57.97	+ 77	+ 56	+13	23.63	+8	37.4		
			21.6737	16.6473	— 27	+1.9	+2.4	40 38 29.17	— 2 6.91	— 11	+ 62	— 4	22.73	+7			
			11.7463 ^u	28.7897 ^{iv}	— 6	+ .1	+ .8	40 29 11.36	+ 7 10.53	+1.04	+ 12	+12	23.17	+8			
		6	29.7930 ^{iv}	10.3117 ⁱⁱ	0	— .3	— .4	40 28 9.86	+ 8 12.12	+1.13	— 10	+13	23.14	+8	37.4		
			13.1393 ⁱⁱ	23.2340 ^{iv}	— 19	+2.6	+2.2	40 30 0.32	+ 6 21.26	+ 94	+ 70	+11	23.33	+8			
			27.4257	11.5597	— 45	0	— .2	40 43 4.76	— 6 40.68	— 60	— 2	— 12	23.34	+8			
			18.3463	21.4823	0	—1.8	— .5	40 37 42.20	— 1 19.21	— 1	— 36	— 3	22.59	+6	37.6		
			17.5220	26.4933	+105	0	+ .2	40 40 10.69	— 3 46.89	— 32	+ 2	— 7	23.43	+7	37.6		
	III	2	3.8333 ⁱⁱ	31.7390 ^{iv}	—104	— .7	—1.0	40 24 37.22	+11 44.67	+1.51	— 24	+21	23.37	+7			
			27.4530	15.0607	+ 94	+ .7	+1.8	40 41 36.96	— 5 13.28	— 47	+ 35	— 8	23.48	+7	37.6		
			18.0923	22.7447	+ 14	+ .3	— .1	40 38 20.58	— 1 57.56	— 13	+ 4	— 4	22.89	+6			
			27.3587	12.6620	0	+ .4	+ .4	40 42 35.40	— 6 11.25	— 49	+ 12	—14	23.64	+5			
			17.3630	23.9570	+ 25	+ .1	+ .9	40 39 9.76	— 2 46.64	— 22	+ 13	— 5	22.98	+5	37.2		
		8	26.8380	15.5873	+ 81	+1.4	+1.7	40 41 8.46	— 4 44.41	— 40	+ 44	—10	23.99	—5			
			15.1520	26.0553	+ 39	+1.4	+1.3	40 31 46.95	+ 4 35.53	+ 56	+ 38	+10	23.52	+4			
			9.2673 ⁱⁱ	30.1623 ^{iv}	0	+ .6	— .2	40 27 34.18	+ 8 47.83	+1.19	+ 7	+15	23.42	+5	36.5		
			15.7380	24.3573	+ 4	+ .6	— 0	40 32 45.27	+ 3 37.75	+ 44	+ 10	+ 7	23.63	—3	33.5		
			23.8717	16.8533	+ 16	—2.0	—1.8	40 33 25.77	+ 2 57.34	+ 36	— 56	+ 5	22.96	—3			
Nov. 3	VI	1 D	24.3933	17.8097	+ 45	— .3	+ .1	40 33 36.87	+ 2 46.42	+ 34	— 4	+ 5	23.64	—3	32.8		
			23.7650	18.6220	+ 36	+ .3	— .6	40 38 33.60	— 2 10.01	— 15	— 3	— 4	23.37	—3			
			10.2963 ⁱⁱ	31.8953 ^{iv}	+ 10	—2.3	—3.7	40 27 16.59	+ 9 5.66	+1.26	— 85	+20	22.86	—3	33.2		
			21.9003	19.8083	+ 10	— .1	— .6	40 37 16.19	— 52.87	— 3	— 10	— 2	23.17	—4	33.1		
			12.4527	28.3503	+ 37	+1.7	+ .5	40 43 5.19	— 6 41.69	— 63	+ 34	—12	23.09	—4			
		9	29.9627 ^{iv}	9.6377 ⁱⁱ	0	0	+ .3	40 27 49.51	+ 8 32.18	+1.18	+ 4	+16	23.07	—4			
			22.7717	16.3907	— 16	0	+ .7	40 33 41.45	+ 2 41.15	+ 33	+ 9	+ 5	23.07	—4	32.8		
			14.6163	27.7633	+ 90	+ .1	+ .1	40 30 50.94	+ 5 32.35	+ 63	+ 3	+10	24.05	—4			
			31.7510	9.7843	+ 97	— .8	+ .1	40 27 7.01	+ 9 15.17	+1.01	— 12	+18	23.25	—4	32.9		
			20.8960	19.9520	+ 3	+1.5	+1.7	40 36 46.79	— 23.85	+ 6	+ 46	— 1	23.45	+7	48.9		
	II	3	28.6093	12.0877	+ 33	— .2	+ .2	40 29 24.32	+ 6 57.40	+ 77	0	+13	22.62	+8	48.5a		
			18.7677	23.7700	+ 39	+ .6	+1.4	40 38 29.33	— 2 6.46	— 11	+ 28	— 4	23.00	+7			
			29.2093 ^{iv}	12.1817 ⁱⁱ	— 12	— .3	+ .9	40 29 11.57	+ 7 10.07	+1.03	+ 6	+12	22.85	+8			
			11.2283 ⁱⁱ	30.6763 ^{iv}	— 2	+1.4	+2.0	40 28 10.11	+ 8 11.24	+1.13	+ 48	+13	23.09	+8	47.6		
			27.6570 ^{iv}	12.5857 ⁱⁱ	— 3	+ .2	+ .2	40 30 0.60	+ 6 20.68	+ 94	+ 6	+11	22.39	+8			
		8	12.6850	28.5583	+ 59	— .5	+ .9	40 43 5.07	— 6 41.09	— 60	+ 4	—12	23.30	+8	48.2		
			22.5243	19.3793	+ 17	— .3	+ .2	40 37 42.52	— 1 19.48	— 1	— 2	— 3	22.98	+7	48.2		
			24.6397	15.6240	+ 6	+2.3	+1.8	40 40 11.09	— 3 47.74	— 32	+ 60	— 7	23.56	+7	48.1		
			20.5303	19.0773	0	+1.0	+ .4	40 37 0.20	— 36.70	+ 7	+ 21	— 1	23.77	+7	48.5		
			18.1353	19.0773	— 10	—1.7	— .9	40 36 46.85	— 23.77	+ 6	— 39	— 1	22.74	+7			
Nov. 6	III	1 R	11.3937	27.9383	— 33	+ .6	+ .2	40 29 24.42	+ 6 57.83	+ 77	+ 12	+13	23.27	+8	47.9		
			21.2317	16.2073	— 39	— .6	— .4	40 38 29.46	— 2 6.82	— 11	— 14	— 4	22.35	+8	47.1		
			11.2983 ⁱⁱ	28.3253 ^{iv}	+ 5	— .7	— .3	40 29 11.72	+ 7 10.11	+1.03	— 16	+12	22.82	+8			
			31.2973 ^{iv}	11.8220 ⁱⁱ	— 6	—1.2	— .7	40 28 10.31	+ 8 11.93	+1.13	— 28	+13	23.22	+8	46.6		
			13.7283 ⁱⁱ	28.8170 ^{iv}	— 37	+1.5	+1.2	40 30 0.82	+ 6 21.04	+ 94	+ 40	+11	23.31	+8			
		8	28.0653	12.1773	+ 11	+ .8	+1.2	40 43 5.31	— 6 41.35	— 60	+ 28	—12	23.52	+8	46.2		
			19.2433	22.3870	+ 15	0	0	40 37 42.77	— 1 19.45	— 1	0	— 3	23.28	+8			
			25.4967	16.4937	+ 54	+ .6	+ .7	40 40 11.41	— 3 47.55	— 32	+ 18	— 7	23.65	+8	46.4		
			34.2377 ^{iv}	6.3920 ⁱⁱ	+ 15	+1.5	0	40 24 37.95	+11 43.40	+1.50	+ 24	+21	23.30	+7	46.1		
			13.7710	25.5513	— 24	— .8	— .4	40 41 21.38	— 4 57.51	— 43	— 18	— 9	23.17	+7	46.0		
	II	4	14.3640	26.7727	+ 41	— .1	— .3	40 41 37.81	— 5 13.54	— 47	— 6	— 9	23.65	+7	45.1		
			23.7810	19.1217	+ 40	— .2	0	40 38 21.44	— 1 57.79	— 13	— 3	— 4	23.45	+6			
			15.0447	29.7273	+205	+1.1	0	40 42 36.23	— 6 11.40	— 49	+ 18	—14	24.38	+5	44.6		
			25.4020	18.8270	+ 82	— .3	—1.4	40 39 10.75	— 2 46.29	— 22	— 23	— 5	23.96	+6	44.4		
			15.8933	27.1733	+102	— .6	—2.3	40 41 9.42	— 4 45.06	— 40	— 40	—10	23.46	+5	43.6		
		5	23.7810	19.1217	+ 40	— .2	0	40 38 21.44	— 1 57.79	— 13	— 3	— 4	23.45	+6			
			15.0447	29.7273	+205	+1.1	0	40 42 36.23	— 6 11.40	— 49	+ 18	—14	24.38	+5	44.6		
			25.4020	18.8270	+ 82	— .3	—1.4	40 39 10.75	— 2 46.29	— 22	— 23	— 5	23.96	+6	44.4		
		8	15.8933	27.1733	+102	— .6	—2.3	40 41 9.42	— 4 45.06	— 40	— 40	—10	23.46	+5	43.6		

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.	
						A	B		Micrometer	δ	l	r				
Nov. 11	II	3	R	13.6173	25.4563	-32	+3.0	+3.2	40 41 22.07	-4 58.98	-43	+90	-9	40 36 23.47	+7	
		4		14.2393	26.6963	+34	+1.4	+1.9	40 41 38.57	-5 14.76	-47	+47	-9	23.72	+7	39.2
		5		23.2953	18.6150	+27	-.8	0	40 38 22.21	-1 58.29	-13	-13	-4	23.62	+6	
		6		12.8933	27.6773	+25	+.7	+.4	40 42 36.96	-6 13.51	-50	+16	-14	22.97	+5	38.8
		7		23.8167	17.1840	+20	-.4	0	40 39 11.59	-2 47.60	-22	-6	-5	23.66	+6	38.8
		8		14.7857	26.0963	+30	+1.0	+1.0	40 41 10.23	-4 45.79	-40	+29	-10	24.23	+5	38.4
		9		27.0773	16.2683	+107	+.4	+2.5	40 31 48.66	+4 33.31	+56	+39	+10	23.02	+5	a
	10		30.3027 ^{iv}	9.4727 ⁱⁱ	0	-1.2	-.5	40 27 36.08	+8 46.18	+1.19	-26	+15	23.34	+5	38.4	
	VI	1	R	23.6223	15.0163	-34	+.5	+.5	40 32 45.59	+3 37.32	+44	+14	+7	23.56	-2	35.1
		2		16.7153	23.7187	+9	+1.4	+1.7	40 33 26.00	+2 56.94	+36	+44	+5	23.79	-3	
		3		13.2563	29.1173	+109	-2.1	-.5	40 43 5.56	-6 40.95	-60	-40	-12	23.49	-3	
		4		18.2550	24.8377	+60	+.4	+1.0	40 33 36.72	+2 46.44	+34	+20	+5	23.75	-3	35.4
	5		16.9640	22.1130	-14	0	0	40 38 33.35	-2 10.04	-15	0	-4	23.12	-3		
	6		31.6453 ^{iv}	10.0510 ⁱⁱ	+8	+.9	+2.2	40 27 16.23	+9 5.53	+1.26	+43	+20	23.65	-3		
	7		19.2590	21.3310	+5	0	+1.1	40 37 15.73	-52.35	-3	+14	-2	23.47	-4		
	8		29.6193	13.8003	+159	+.7	-.2	40 43 4.56	-6 40.01	-60	+9	-12	23.92	-4	34.7	
	9		10.8737 ⁱⁱ	31.2003 ^{iv}	0	0	-.4	40 27 48.70	+8 33.48	+1.18	-5	+16	23.47	-4	34.7	
	10		18.1947	24.5880	+53	+2.4	+3.1	40 33 40.44	+2 41.64	+33	+79	+5	23.25	-4	34.3	
	11		27.3423	14.2000	+59	+.7	+.7	40 30 49.80	+5 32.14	+63	+20	+10	22.87	-4		
	12		11.0237	33.0377	+264	-.9	-.9	40 27 5.72	+9 16.77	+1.02	-26	+18	23.43	-4	34.0	
Nov. 15	II	1	R	20.2487	21.7023	+8	-1.0	-.3	40 37 0.39	-36.74	+7	-20	-1	23.51	+7	
		2		21.8337	20.9147	+7	-2.9	-2.7	40 36 47.12	-23.23	+6	-82	-1	23.12	+7	36.6
		3		29.4233	12.9283	+114	+.7	0	40 29 24.80	+6 56.98	+77	+12	+13	22.80	+8	36.2
		4		19.5950	24.6043	+61	-.7	-.3	40 38 29.95	-2 6.70	-11	-16	-4	22.94	+7	
		5		29.0527 ^{iv}	12.0497 ⁱⁱ	-10	-.4	-.5	40 29 12.28	+7 9.50	+1.03	-13	+12	22.80	+8	
		6		10.9813 ⁱⁱ	30.4260 ^{iv}	0	+.3	0	40 28 11.03	+8 11.20	+1.13	+5	+13	23.54	+8	35.2
		7		27.9723	12.9323	+40	+.4	+.7	40 30 1.61	+6 20.04	+69	+16	+11	22.61	+8	
		8		13.3687	29.2637	+123	-.8	+1.1	40 43 6.19	-6 41.84	-61	+2	-12	23.64	+8	35.5
	III	9	R	22.8100	19.6630	+23	-1.8	-.2	40 37 43.71	-1 19.55	-1	-32	-3	23.80	+7	
		1	D	15.9570	25.0047	+27	-1.7	-1.7	40 40 12.51	-3 48.63	-32	-50	-7	22.99	+8	35.1
		2		4.3587 ⁱⁱ	32.1950 ^{iv}	-80	0	-1.6	40 24 39.11	+11 42.98	+1.50	-21	+21	23.59	+8	34.9
		3		26.0907	14.2400	+12	+.2	+.3	40 41 22.60	-4 59.40	-43	+7	-9	22.75	+7	
		4		27.1437	14.6747	+66	+.2	-.6	40 41 39.14	-5 15.15	-47	-5	-9	23.38	+7	34.4
		5		17.9140	22.6567	-8	-.5	-.8	40 38 22.81	-1 59.79	-13	-18	-4	22.67	+6	
		6		26.5843	11.7853	-71	+1.4	+.2	40 42 37.56	-6 13.67	-50	+25	-14	22.50	+6	33.9
		7		17.1930	23.8570	+20	-1.6	-.4	40 39 12.29	-2 48.39	-22	-31	-5	23.32	+6	33.6
		8		24.7637	13.4140	-61	-.4	-.6	40 41 10.93	-4 46.56	-40	-14	-10	23.73	+5	
		9		14.3247	25.1500	-17	-1.7	-2.8	40 31 49.35	+4 33.42	+56	-64	+10	22.79	+5	33.6
I	1	D	13.2557	21.8890	-124	+.1	-2.5	40 32 45.89	+3 37.78	+44	-31	+7	23.87	-1	31.1	
	2		24.2337	17.2727	+31	+.9	+2.2	40 33 26.27	+2 55.93	+36	+43	+5	23.04	-3		
	3		27.6823	11.8067	-23	-1.8	-.6	40 43 5.77	-6 40.99	-60	-37	-12	23.69	-3	30.7	
	4		24.1097	17.5900	+34	+1.1	+1.5	40 33 36.85	+2 44.79	+34	+37	+5	22.40	-3		
	5		22.4503	17.2890	-4	0	0	40 38 33.43	-2 10.38	-15	0	-4	22.86	-3	30.4	
	6		7.7110 ⁱⁱ	29.3110 ^{iv}	-15	+1.7	+.6	40 27 16.25	+9 5.63	+1.26	+36	+20	23.70	-3		
	7		21.3807	19.2960	+6	+.3	+.1	40 37 15.72	-52.68	-3	+6	-2	23.05	-4		
	8		12.8653	28.7393	+76	-.4	+.7	40 43 4.50	-6 41.20	-60	+2	-12	22.60	-4	30.8	
	9		29.4223 ^{iv}	9.1107 ⁱⁱ	0	-.7	+.7	40 27 48.55	+8 33.12	+1.18	-2	+16	22.99	-4	30.2	
	10		23.4587	17.0253	+10	+.2	+.1	40 33 40.23	+2 42.55	+33	+4	+5	23.20	-4		
	11		13.0977	26.2907	-23	-.2	-.7	40 30 49.55	+5 33.23	+63	-12	+10	23.39	-4		
Nov. 16	VI	12		29.5073	7.4477	-200	-2.2	-.9	40 27 5.38	+9 16.77	+1.02	-47	+18	22.88	-4	29.9
Nov. 16	II	1	D	20.2760	18.8000	-3	+1.9	+1.0	40 37 0.35	-37.28	+7	+44	-1	23.57	+7	34.1
		2		19.1177	20.0833	-3	-1.0	0	40 36 47.09	-24.38	+6	-16	-1	22.60	+7	
		3		11.3123	27.8740	-41	-.4	-2.3	40 29 24.78	+6 58.28	+77	-36	+13	23.60	+8	33.9
		4		20.7003	15.6737	-54	-1.2	-.4	40 38 29.95	-2 6.84	-11	-24	-4	22.72	+7	
		5		11.9890 ⁱⁱ	28.9993 ^{iv}	-9	+.5	-1.1	40 29 12.31	+7 9.69	+1.03	-6	+12	23.09	+8	

1893	Pair	P	Micrometer	C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude		Δ	Ther.	
					A	B		Micrometer	δ	l	r					
Dec. 4	II	6 R	10.5067 ^{II}	29.9317 ^{IV}	0	+2.3	+2.7	0 28 11.06	+ 8 10.74	+1.03	+ 72	+13	40 36 23.68	+8		
		7	27.6140 ^{IV}	12.5617 ^{II}	- 3	+ .6	+ .9	40 30 1.78	+ 6 20.26	+ 82	+ 21	+11	23.18	+8		
		8	12.7937	28.7493	+ 72	+1.6	+1.7	40 43 6.61	- 6 43.28	- 68	+ 48	-12	23.01	+7	26.8	
	III	9	23.9800	20.7893	+ 44	- .6	+ .1	40 37 44.45	- 1 20.72	- 3	- 8	- 3	23.59	+7		
		1	24.0407	14.9240	- 29	+1.4	+ .6	40 40 13.43	- 3 50.24	- 37	+ 30	- 7	23.05	+8	26.3	
		2	32.9033 ^{IV}	5.1437 ^{II}	- 46	- .8	+ .9	40 24 40.20	+11 41.18	+1.44	- 2	+21	23.01	+7		
		3	14.6787	26.5587	+ 46	+1.9	+1.3	40 41 23.87	- 5 0.24	- 49	+ 48	- 9	23.53	+7		
		4	15.1763	27.7290	+109	+1.2	+1.4	40 41 40.66	- 5 17.39	- 53	+ 33	- 9	23.03	+7	25.8	
		5	23.8393	19.0463	+ 41	- .2	+ .6	40 38 24.54	- 2 1.19	- 16	+ 5	- 4	23.20	+7	25.4	
		6	14.2107	29.0733	+141	+2.1	+1.0	40 42 39.37	- 6 15.83	- 56	+ 47	-14	23.31	+6		
		7	24.5690	17.8160	+ 47	+1.4	+ .4	40 39 14.45	- 2 50.72	- 26	+ 28	- 5	23.70	+7	25.2	
		8	15.4877	26.9547	+ 83	+1.8	+1.8	40 41 13.16	- 4 49.90	- 46	+ 52	-10	23.22	+6		
		9	26.4740	15.7837	+ 74	+1.7	+1.5	40 31 51.58	+ 4 30.26	+ 60	+ 47	+10	23.01	+6		
		10	30.9723 ^{IV}	10.2640 ^{II}	0	-2.3	-1.6	40 27 39.28	+ 8 43.16	+1.09	- 58	+15	23.10	+6	24.1	
		V	7 R	13.8793	28.9273	+122	+ .5	+1.5	40 42 43.74	- 6 20.49	- 63	+ 28	-13	22.77	0	20.2
Dec. 5		8	19.4873	23.8060	+ 41	+1.1	+2.0	40 34 32.16	+ 1 50.48	+ 29	+ 44	+ 4	23.41	-1		
		9	14.0233	28.0180	+ 84	-1.4	- .5	40 42 17.58	- 5 53.77	- 60	- 29	-10	22.82	-1		
		10	23.8967	20.6393	+ 43	+ .4	+ .6	40 37 46.05	- 1 22.41	- 9	+ 14	- 3	23.66	-1	20.4	
	VI	2	17.6537	24.5630	+ 45	+4.8	+3.7	40 33 27.36	+ 2 54.67	+ 39	+1.26	+ 5	23.73	-2		
		V	7 D	24.3097	9.2417	-288	- .7	-1.0	40 42 43.80	- 6 19.95	- 63	- 24	-13	22.85	0	22.2
			8	21.8680	17.4967	- 10	-1.8	-1.1	40 34 32.21	+ 1 50.41	+ 29	- 44	+ 4	22.51	0	
	9		27.2360	13.2353	+ 20	- .2	-2.2	40 42 17.63	- 5 53.76	- 60	- 32	-10	22.85	-1	22.5	
		10	17.6740	20.9463	- 14	- .2	- .6	40 37 46.10	- 1 22.63	- 8	- 11	- 3	23.25	-1		
		VI	1	15.3730	23.9283	- 18	-1.1	-1.6	40 32 47.10	+ 3 36.10	+ 47	- 38	+ 7	23.36	-1	21.4
			2	22.1087	15.1550	- 56	+ .5	+ .2	40 33 27.35	+ 2 55.54	+ 39	+ 10	+ 5	23.43	-2	
	3		28.5230	12.6050	+ 51	-1.2	-1.2	40 43 6.68	- 6 42.28	- 68	- 35	-12	23.25	-2		
		4	23.2650	16.7000	0	-1.9	-1.4	40 33 37.33	+ 2 45.86	+ 37	- 48	+ 5	23.18	-2	21.4	
		5	21.9487	16.8077	- 22	- .5	-2.1	40 38 33.80	- 2 9.82	- 17	- 36	- 4	23.41	-3		
		II	6	8.5967 ^{II}	30.1937 ^{IV}	- 5	+ .4	+ .3	40 27 16.36	+ 9 5.61	+1.17	+ 10	+20	23.44	-3	20.9
	2 D		18.2257	19.1483	- 7	0	- .4	40 36 46.22	- 23.29	+ 6	- 5	- 1	22.93	+6	27.0	
3	10.4123		26.9753	-129	+ .7	+1.0	40 29 24.01	+ 6 58.11	+ 85	+ 24	+13	23.34	+7			
Dec. 6		4	22.7350	17.7217	+ 5	-1.1	-1.0	40 38 29.55	- 2 6.67	- 14	- 30	- 4	22.40	+7		
		6	30.2470 ^{IV}	10.7171 ^{II}	0	-2.3	-2.9	40 28 10.93	+ 8 12.01	+1.03	- 74	+13	23.38	+8	25.9	
		7	13.2210 ^{II}	28.2960 ^{IV}	- 24	+ .1	+1.5	40 30 1.72	+ 6 20.79	+ 82	+ 21	+11	23.65	+8		
		8	27.8197	11.9000	- 14	- .4	- .3	40 43 6.59	- 6 42.15	- 68	- 10	-12	23.54	+7	25.5	
		III	1	16.4817	25.5653	+ 55	-1.1	-1.0	40 40 13.45	- 3 49.63	- 37	- 30	- 7	23.09	+8	
			2	4.8777 ^{II}	32.6633 ^{IV}	- 57	- .8	0	40 24 40.23	+11 41.81	+1.44	- 13	+21	23.56	+7	
	3		25.6767	13.7683	- 20	+1.5	+2.0	40 41 23.92	- 5 0.79	- 49	+ 50	- 9	23.05	+7		
		4	26.0023	13.4517	- 20	+1.8	+1.5	40 41 40.74	- 5 17.02	- 53	+ 48	- 9	23.58	+7	25.5	
		5	17.2400	22.0443	- 13	-1.1	-1.3	40 38 24.64	- 2 1.34	- 15	- 34	- 4	22.77	+7		
		6	26.1880	11.3410	-107	- .2	- .7	40 42 39.49	- 6 14.81	- 57	- 12	-14	23.85	+6		
		7	17.0940	23.8753	+ 21	+ .4	- .5	40 39 14.55	- 2 51.38	- 26	0	- 5	22.86	+7		
		8	26.1163	14.6597	+ 26	- .4	+ .4	40 41 13.30	- 4 49.50	- 46	- 2	-10	23.22	+6	23.9	
		9	14.1570	24.8890	- 31	-1.2	-1.5	40 31 51.73	+ 4 31.05	+ 61	- 39	+10	23.10	+6		
		10	10.7787 ^{II}	31.4697 ^{IV}	+ 4	- .9	- .9	40 27 39.45	+ 8 42.74	+1.09	- 26	+15	23.17	+6	23.6	
		III	1 R	24.5037	15.4143	0	+ .1	- .1	40 40 13.46	- 3 49.63	- 37	0	- 7	23.39	+8	30.3
2			33.7700 ^{IV}	6.0390 ^{II}	- 3	+2.8	+1.2	40 24 40.26	+11 40.55	+1.44	+ 60	+21	23.06	+7	30.4	
3	13.4237		25.3037	- 47	-1.0	- .2	40 41 23.96	- 5 0.00	- 49	- 18	- 9	23.20	+7	30.4		
Dec. 7		4	14.0387	26.5890	+ 25	- .7	- .2	40 41 40.79	- 5 17.12	- 53	- 14	- 9	22.91	+7		
		5	23.5087	18.7177	+ 32	- .3	0	40 38 24.70	- 2 1.11	- 15	- 5	- 4	23.35	+7		
		6	14.2770	29.0987	+147	- .5	- .5	40 42 39.56	- 6 14.80	- 57	- 14	-14	23.91	+6	29.6	
		7	23.9390	17.1823	+ 21	-1.3	- .4	40 39 14.64	- 2 50.75	- 26	- 26	- 5	23.32	+7		
		8	15.6683	27.0867	+ 95	- .5	- .3	40 41 13.40	- 4 48.70	- 46	- 12	-10	24.02	+6		
		9	27.0713	16.3660	+109	- .4	- .1	40 31 51.82	+ 4 30.72	+ 61	- 8	+10	23.17	+6		
		10	31.0177 ^{IV}	10.3567 ^{II}	0	- .3	+1.2	40 27 39.55	+ 8 41.95	+1.08	+ 10	+15	22.83	+6		

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude			Δ	Ther.
						A	B		Micrometer	δ	l	r					
Dec. 7	V 7 R		14.5463	29.5327	+179	-2.1	-1.6	40 42 43.94	- 6 19.06	- 63	- 55	-13	40 36 23.57	0	21.1		
			17.7953	22.1997	0	-1.8	-2.4	40 34 32.33	+ 1 51.27	+ 29	- 60	+ 4	23.33	0			
			13.4833	27.4533	+ 40	-2.8	-2.6	40 42 17.77	- 5 53.04	- 60	- 79	-10	23.24	-1			
			22.4103	19.1627	+ 15	- .8	-1.4	40 37 46.20	- 1 22.08	- 8	- 31	- 3	23.70	-1			
			25.3350	16.7837	+ 55	-1.8	- .6	40 32 47.19	+ 3 36.18	+ 47	- 37	+ 7	23.54	-1	22.6		
	VI 1		17.1067	24.0593	+ 23	-1.2	-1.4	40 33 27.44	+ 2 55.71	+ 39	- 38	+ 5	23.21	-2			
			13.1127	29.0020	+ 96	- .1	-1.6	40 43 6.74	- 6 41.67	- 68	- 22	-12	24.05	-2	21.6		
			17.9750	24.5657	+ 52	-1.3	-1.2	40 33 37.41	+ 2 46.64	+ 37	- 36	+ 5	24.11	-2			
			17.3123	22.4897	- 4	0	+ .6	40 38 33.81	- 2 10.79	- 17	+ 8	- 4	22.89	-3			
			16.1077	25.2177	+ 36	+ .4	+1.8	40 40 13.53	- 3 50.23	- 37	+ 30	- 7	23.16	+7	34.3		
Dec. 10	III 1 D		5.0630 ^{II}	32.8340 ^{IV}	- 50	- .4	- .1	40 24 40.36	+11 41.42	+1.44	- 8	+21	23.35	+7			
			26.8923	15.0003	+ 67	+ .2	+ .4	40 41 24.09	- 5 0.58	- 49	+ 8	- 9	23.01	+7	34.2		
			26.6530	14.0977	+ 28	- .6	-2.0	40 41 40.95	- 5 17.24	- 53	- 36	- 9	22.73	+7	34.1		
			17.4637	22.2893	- 4	+ .5	- .3	40 38 24.92	- 2 1.89	- 16	+ 4	- 4	22.87	+7			
			27.5803	12.7113	+ 12	+ .1	+ .2	40 42 39.82	- 6 15.65	- 57	+ 4	-14	23.50	+6	33.2		
	V 7 D		17.7543	24.5413	+ 48	- .2	- .4	40 39 14.93	- 2 51.57	- 26	- 8	- 5	22.97	+7	33.1		
			25.5970	14.1230	- 9	+ .3	- .5	40 41 13.72	- 4 49.83	- 46	- 2	-10	23.31	+6			
			13.0147	23.7343	-103	+ .1	0	40 31 52.16	+ 4 30.53	+ 60	0	+10	23.39	+6			
			9.8953 ^{II}	30.5750 ^{IV}	0	+ .2	- .3	40 27 39.90	+ 8 42.40	+1.08	- 1	+15	23.52	+6	32.9		
			26.7513	11.6917	- 68	0	+ .4	40 42 44.27	- 6 20.27	- 63	+ 5	-13	23.29	0	31.4		
Dec. 12	VI 1		23.0380	18.6803	+ 23	-1.0	- .3	40 34 32.63	+ 1 50.14	+ 28	- 20	+ 4	22.89	0			
			28.3223	14.3107	+108	+ .4	+ .7	40 42 18.09	- 5 54.24	- 60	+ 16	-10	23.31	0			
			17.7753	21.0773	- 14	+ .5	+ .3	40 37 46.49	- 1 23.38	- 9	+ 12	- 3	23.11	-1	31.1		
			16.2233	24.7353	+ 24	+1.2	+ .8	40 32 47.45	+ 3 35.09	+ 47	+ 30	+ 7	23.38	-1			
			22.4947	15.5277	- 41	-2.2	-2.3	40 33 27.68	+ 2 55.90	+ 39	- 66	+ 5	23.36	-1	31.4		
	III 1 R		29.0163	13.0990	+ 97	- .2	+1.3	40 43 6.96	- 6 42.35	- 68	+ 14	-12	23.95	-2	31.0		
			22.9367	16.4053	- 15	- .5	- .9	40 33 37.58	+ 2 44.96	+ 37	- 20	+ 5	22.76	-2			
			21.8650	16.6947	- 22	- .5	-1.0	40 38 33.94	- 2 10.55	- 17	- 21	- 4	22.97	-2			
			8.4937 ^{II}	30.0853 ^{IV}	- 7	+ .8	+ .5	40 27 16.43	+ 9 5.44	+1.17	+ 20	+20	23.44	-2	31.5		
			24.3617	15.2380	- 11	+ .9	+1.9	40 40 13.50	- 3 50.45	- 37	+ 39	- 7	23.00	+7	35.6		
Dec. 13	VI 2		33.9073 ^{IV}	6.1720 ^{II}	0	- .6	- .2	40 24 40.36	+11 40.64	+1.44	- 12	+21	22.53	+7			
			12.2327	24.1467	-126	- .1	+ .4	40 41 24.11	- 5 0.65	- 49	+ 4	- 9	22.92	+7	35.1		
			14.7793	27.3823	+ 81	+ .4	0	40 41 41.01	- 5 18.57	- 53	+ 6	- 9	21.88	+7			
			23.8980	19.0797	+ 42	+ .3	- .6	40 38 25.02	- 2 1.82	- 16	- 3	- 4	22.97	+7			
			13.9507	28.8090	+123	+ .5	+ .1	40 42 39.95	- 6 15.65	- 57	+ 10	-14	23.69	+6	34.7		
	V 7 R		23.2857	16.4833	- 4	- .1	+ .2	40 39 15.08	- 2 51.83	- 26	+ 1	- 5	22.95	+7			
			16.3140	27.7880	+138	- .2	- .3	40 41 13.90	- 4 50.20	- 46	- 7	-10	23.07	+6	34.1		
			26.7163	16.0470	+ 89	- .2	- .6	40 31 52.35	+ 4 29.75	+ 60	- 11	+10	22.69	+6			
			30.5400 ^{IV}	9.8947 ^{II}	0	- .2	- .6	40 27 40.09	+ 8 41.53	+1.08	- 11	+15	22.74	+6	33.9		
			15.6900	24.7970	+ 14	+ .7	+ .4	40 40 13.47	- 3 50.13	- 37	+ 16	- 7	23.06	+7	18.1		
Dec. 13	VI 1		3.8957 ^{II}	31.6513 ^{IV}	-101	+1.3	+1.9	40 24 40.32	+11 40.98	+1.44	+ 46	+21	23.41	+7			
			26.2090	14.2867	+ 16	+1.3	+1.8	40 41 24.09	- 5 1.25	- 49	+ 44	- 9	22.70	+7			
			26.8303	14.2760	+ 39	+ .6	- .1	40 41 41.01	- 5 17.29	- 53	+ 8	- 9	23.18	+7	18.3		
			17.9203	22.7453	+ 11	+ .6	+1.0	40 38 25.05	- 2 1.93	- 16	+ 22	- 4	23.14	+7			
			26.1287	11.2087	-118	+1.3	+1.9	40 42 39.99	- 6 16.66	- 57	+ 46	-14	23.08	+6	18.0		
	V 7 R		17.8160	24.6123	+ 48	+ .3	+1.3	40 39 15.12	- 2 51.83	- 26	+ 22	- 5	23.20	+7			
			26.5167	15.0230	+ 52	+1.9	+2.1	40 41 13.96	- 4 50.52	- 46	+ 58	-10	23.46	+6			
			14.1590	24.8543	- 31	+ .8	- .2	40 31 52.42	+ 4 30.14	+ 60	+ 10	+10	23.36	+6			
			8.9130 ^{II}	29.5737 ^{IV}	0	+ .5	- .4	40 27 40.18	+ 8 41.99	+1.08	+ 3	+15	23.43	+6	17.5		
			12.7557	27.7977	+ 23	+2.2	- .4	40 42 44.68	- 6 20.09	- 63	+ 30	-13	24.13	0	15.6		
Dec. 13	VI 2		18.1977	22.5723	+ 12	-2.1	-1.6	40 34 33.03	+ 1 50.55	+ 29	- 55	+ 4	23.36	0			
			13.7100	27.6977	+ 57	-4.0	-2.4	40 42 18.51	- 5 53.54	- 60	- 96	-10	23.31	0	17.2		
			22.5110	19.2193	+ 16	+1.0	- .2	40 37 46.88	- 1 23.21	- 9	+ 14	- 3	23.69	-1			
			25.7257	17.2580	+ 74	- .6	- .4	40 32 47.82	+ 3 34.12	+ 47	- 14	+ 7	22.34	-1			
			16.8790	23.8333	+ 15	-2.0	- .9	40 33 28.05	+ 2 55.74	+ 39	- 44	+ 5	23.79	-1			

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude	Δ	Ther.
						A	B		Micrometer	δ	l	r			
Dec. 13	III 4	D	17.9490	24.5583	+ 49	-1.8	-1.2	40 33 37.87	+ 2 47.10	+ 37	- 44	+ 5	40 36 24.95	-2	17.0
	5		17.3163 ^{iv}	22.5140 ^{iv}	-310	+ .2	+ .1	40 38 34.21	- 2 10.54	- 17	+ 4	- 4	23.50	-2	
Dec. 17	6		32.3253 ^{iv}	10.7230 ⁱⁱ	+ 14	-1.1	- .6	40 27 16.65	+ 9 5.81	+1.17	- 26	+20	23.57	-2	16.6
	III 1	R	24.1183	15.0483	- 23	- .3	-2.4	40 40 13.19	- 3 49.05	- 37	- 36	- 7	23.34	+7	
Dec. 20	III 1	R	23.7703	14.6727	- 42	+1.4	+ .1	40 40 13.09	- 3 49.73	- 37	+ 24	- 7	23.16	+7	28.0
	2		33.6097 ^{iv}	5.8403 ⁱⁱ	- 12	+ .7	+1.4	40 24 40.01	+11 41.51	+1.44	+ 30	+21	23.47	+7	
	3		14.8150	26.6960	+ 53	+1.1	+ .6	40 41 23.86	- 5 0.28	- 49	+ 26	- 9	23.26	+7	
	4		14.2567	26.7870	+ 38	- .3	- .6	40 41 40.86	- 5 16.65	- 53	- 13	- 9	23.46	+7	27.4
	5		23.5090	18.6880	+ 32	- .8	-1.2	40 38 25.02	- 2 1.88	- 16	- 28	- 4	22.66	+6	27.3
	6		14.2557	29.1213	+145	- .2	- .3	40 42 40.07	- 6 15.92	- 57	- 7	-14	23.37	+6	
	7		23.3470	16.5733	- 2	-1.0	- .5	40 39 15.24	- 2 51.11	- 26	- 22	- 5	23.60	+7	
	8		14.8080	26.2570	+ 35	-1.1	-1.1	40 41 14.19	- 4 49.33	- 46	- 32	-10	23.98	+6	27.1
	9		26.9393	16.2470	+100	-1.8	- .9	40 31 52.68	+ 4 30.38	+ 60	- 40	+10	23.36	+6	
	10		31.1037 ^{iv}	10.4560 ⁱⁱ	+ 3	-2.6	-1.4	40 27 40.47	+ 8 41.63	+1.08	- 60	+15	22.73	+6	26.4
	V 7	D	26.8353	11.7283	- 63	+2.1	+ .1	40 42 45.30	- 6 21.49	- 63	+ 36	-13	23.41	+1	26.2
	8		22.1543	17.8253	0	- .8	0	40 34 33.61	+ 1 49.36	+ 28	- 13	+ 4	23.16	0	
	9		27.3103	13.2810	+ 22	+ .2	- .9	40 42 19.15	- 5 54.48	- 60	- 8	-10	23.89	0	
	10		17.5857	20.9257	- 15	+1.4	+ .1	40 37 47.45	- 1 24.34	- 9	+ 24	- 3	23.23	0	
	VI 1		15.6803	24.1877	0	- .6	-1.1	40 32 48.36	+ 3 34.92	+ 47	- 24	+ 7	23.58	-1	26.2
	2		23.4403	16.5520	0	-1.1	-1.0	40 33 28.55	+ 2 54.02	+ 38	- 30	+ 5	22.70	-1	
	3		27.8060	11.8413	- 16	-1.0	- .4	40 43 7.76	- 6 43.27	- 68	- 21	-12	23.48	-1	26.0
	4		23.4853	16.9740	+ 9	0	+ .5	40 33 38.28	+ 2 44.52	+ 37	+ 6	+ 5	23.28	-2	25.6
	5		20.6853	15.5013	- 58	- .7	-1.8	40 38 34.57	- 2 10.82	- 17	- 35	- 4	23.19	-2	
Dec. 23	6		7.9370 ⁱⁱ	29.5147 ^{iv}	- 11	- .1	-1.0	40 27 16.92	+ 9 5.09	+1.17	- 14	+20	23.24	-2	25.6
	III 1	D	16.3233	25.4327	+ 47	+2.5	+2.7	40 40 12.97	- 3 50.22	- 37	+ 75	- 7	23.06	+7	44.3
	2		5.3713 ⁱⁱ	33.1177 ^{iv}	- 37	+1.5	+2.2	40 24 39.97	+11 40.78	+1.44	+ 52	+21	22.92	+6	
	3		25.7470	13.8287	- 15	+1.8	+2.5	40 41 23.86	- 5 1.01	- 49	+ 62	- 9	22.89	+6	
	4		25.2740	12.6603	- 77	- .1	+ .2	40 41 40.88	- 5 18.42	- 53	+ 1	- 9	21.85	+7	43.9
	5		16.9263	21.7923	- 18	+1.4	+1.2	40 38 25.12	- 2 2.87	- 16	+ 38	- 4	22.43	+6	
	6		26.2500	11.2993	-106	+1.2	+2.1	40 42 40.23	- 6 17.38	- 58	+ 47	-14	22.60	+6	
	7		17.0940	23.9110	+ 21	+ .3	+ .5	40 39 15.40	- 2 52.25	- 26	+ 12	- 5	22.96	+7	42.6
	9		12.4247	23.0953	-143	+ .3	+ .5	40 31 52.91	+ 4 29.17	+ 60	+ 12	+10	22.90	+6	
Dec. 24	10		9.7820 ⁱⁱ	30.3983 ^{iv}	0	+ .9	0	40 27 40.70	+ 8 40.76	+1.08	+ 14	+15	22.83	+6	43.3
	III 1	R	24.8353	15.7573	+ 18	0	- .7	40 40 12.94	- 3 49.35	- 37	- 9	- 7	23.06	+7	43.5
	2		33.6073 ^{iv}	5.8253 ⁱⁱ	- 12	-1.8	- .4	40 24 39.95	+11 41.74	+1.44	- 34	+21	23.00	+6	
	3		14.8813	26.7197	+ 57	-3.0	-4.3	40 41 23.86	- 4 59.18	- 49	-1.04	- 9	23.06	+6	
	4		14.4547	26.9967	+ 54	+ .2	- .5	40 41 40.89	- 5 16.95	- 53	- 4	- 9	23.28	+7	43.2
	5		23.7753	18.9713	+ 40	-1.2	-2.3	40 38 25.14	- 2 1.45	- 16	- 50	- 4	22.99	+6	
	6		14.3063	29.1707	+149	- .2	0	40 42 40.27	- 6 15.86	- 57	- 3	-14	23.67	+6	42.2
	7		24.1877	17.3863	+ 33	+ .9	+ .4	40 39 15.45	- 2 51.88	- 26	+ 20	- 5	23.46	+7	
	8		15.1530	26.6437	+ 62	- .6	- .2	40 41 14.46	- 4 50.41	- 46	- 12	-10	23.37	+6	
	9		26.4000	15.7607	+ 67	- .1	0	40 31 53.00	+ 4 28.91	+ 60	- 2	+10	22.59	+6	
	10		31.1050 ^{iv}	10.4520 ⁱⁱ	0	-1.6	-1.5	40 27 40.77	+ 8 41.70	+1.08	- 46	+15	23.24	+6	42.0
	V 7	R	12.3100	27.4207	- 12	+2.9	- .7	40 42 45.75	- 6 21.66	- 63	+ 38	-13	23.71	+1	43.4
	8		19.3173	23.5993	+ 37	+1.1	- .3	40 34 34.03	+ 1 48.26	+ 28	+ 14	+ 4	22.75	0	
	9		14.2723	28.3573	+110	+ .4	+ .8	40 42 19.60	- 5 56.07	- 60	+ 17	-10	23.00	0	
	10		23.2217	19.8653	+ 31	- .8	+2.7	40 37 47.87	- 1 24.86	- 9	+ 22	- 3	23.11	0	
	VI 1		25.1407	16.6877	+ 46	+ .2	+ .1	40 32 48.74	+ 3 33.64	+ 47	+ 4	+ 7	23.96	0	44.0
	2		17.3830	24.2353	+ 31	+ .5	+1.2	40 33 28.97	+ 2 53.17	+ 38	+ 24	+ 5	22.81	-1	
	3		12.0543	28.0690	+ 5	+1.0	+1.1	40 43 8.04	- 6 44.54	- 68	+ 30	-12	23.00	-1	
	4		17.7723	24.2717	+ 40	0	+1.1	40 33 38.57	+ 2 44.27	+ 37	+ 14	+ 5	23.40	-2	
	5		18.2770	23.4760	+ 27	- .3	- .3	40 38 34.82	- 2 11.39	- 18	- 9	- 4	23.12	-2	
Dec. 25	6		32.2200 ^{iv}	10.6517 ⁱⁱ	+ 13	+ .7	+ .4	40 27 17.12	+ 9 4.84	+1.17	+ 16	+20	23.49	-2	43.7
	III 1	D	16.1103	25.2030	+ 35	+1.4	+1.3	40 40 12.88	- 3 49.75	- 37	+ 40	- 7	23.09	+6	52.4
	2		4.7813 ⁱⁱ	32.5257 ^{iv}	- 61	+ .8	+1.2	40 24 39.91	+11 40.63	+1.44	+ 28	+21	22.47	+6	

1893	Pair	P	Micrometer		C	Levels		$\frac{1}{2}(\delta + \delta')$	Corrections				Latitude		Δ	Ther.
						A	B		Micrometer	δ	l	r				
Dec. 25	III 3	D	24.5020	12.5593	-104	+ .7	+ .7	40 41 23.82	- 5	1.40	- 49	+ 20	- 9	40 36 22.04	+6	
			25.4063	12.8047	- 67	+1.8	+2.0	40 41 40.87	- 5	18.13	- 53	+ 55	- 9	22.67	+7	52.0
			17.4017	22.2273	- 6	- .6	- .7	40 38 25.18	- 2	1.87	- 16	- 18	- 4	22.93	+6	
			24.8773	9.9337	-228	+1.4	+ .9	40 42 40.31	- 6	16.87	- 57	+ 34	-14	23.07	+5	51.8
			16.4333	23.2703	- 6	+ .2	+ .4	40 39 15.49	- 2	52.68	- 26	+ 8	- 5	22.58	+6	51.5
	V 8		24.9827	13.4460	- 53	+1.2	+ .7	40 41 14.53	- 4	51.27	- 46	+ 28	-10	22.98	+6	
			13.7100	24.3703	- 62	+1.1	+1.0	40 31 53.06	+ 4	29.11	+ 60	+ 30	+10	23.17	+5	
			9.4783 ^u	30.1137 ^v	0	+ .5	0	40 27 40.84	+ 8	41.22	+1.08	+ 8	+15	23.37	+6	50.8
			26.5737	11.4430	- 87	+ .9	+ .2	40 42 45.90	- 6	21.96	- 63	+ 17	-13	23.35	+1	50.2
			21.9587	17.6617	- 5	- .3	-1.8	40 34 34.17	+ 1	48.53	+ 28	- 28	+ 4	22.74	+1	
VI 1		26.9063	12.8427	- 12	- .6	+ .4	40 42 19.75	- 5	55.19	- 60	- 4	-10	23.82	0		
		16.4607	19.8190	- 37	+1.4	+ .4	40 37 48.01	- 1	24.74	- 9	+ 28	- 3	23.43	0		
		15.6313	24.0823	- 8	+ .2	+ .7	40 32 48.87	+ 3	33.44	+ 47	+ 12	+ 7	22.97	0	49.2	
		23.1593	16.3090	- 12	+1.3	+3.2	40 33 29.10	+ 2	53.00	+ 38	+ 62	+ 5	23.15	-1		
		27.1517	11.1357	- 79	+ .4	+1.4	40 43 8.22	- 6	44.34	- 68	+ 24	-12	23.32	-1	49.7	
Dec. 26	III 1	R	24.0003	14.9100	- 30	+2.0	+1.7	40 40 12.80	- 3	49.57	- 37	+ 54	- 7	23.33	+6	28.7
			33.8933 ^v	6.1453 ^u	0	+1.3	+1.7	40 24 39.84	+11	41.00	+1.44	+ 43	+21	22.92	+6	28.4
			16.9753	28.8497	+204	+1.8	+1.8	40 41 23.78	- 5	0.50	- 49	+ 52	-10	23.21	+6	28.2
			14.0523	26.5877	+ 25	+ .7	+ .8	40 41 40.84	- 5	16.74	- 53	+ 22	- 9	23.70	+7	
			23.5933	18.7430	+ 34	+1.9	+2.1	40 38 25.15	- 2	2.62	- 16	+ 58	- 4	22.91	+6	
	V 7	R	14.1067	28.9797	+133	+ .8	+1.2	40 42 40.32	- 6	16.07	- 57	+ 28	-14	23.82	+5	
			23.7340	16.9140	+ 14	+2.0	+1.2	40 39 15.50	- 2	52.33	- 26	+ 48	- 5	23.34	+6	27.9
			15.5997	27.1217	+ 92	+2.2	+2.6	40 41 14.56	- 4	51.31	- 46	+ 70	-10	23.39	+6	
			27.2557	16.6220	+122	+2.0	+2.9	40 31 53.11	+ 4	28.94	+ 60	+ 70	+10	23.45	+5	
			30.3373 ^v	9.7530 ^u	0	+1.9	+1.9	40 27 40.90	+ 8	40.02	+1.08	+ 55	+15	22.70	+6	27.1
VI 1		15.3253	30.4460	+258	0	- .1	40 42 46.04	- 6	22.65	- 63	- 2	-13	22.61	+1	25.9	
		18.3097	22.6047	+ 13	-3.7	-3.5	40 34 34.32	+ 1	48.53	+ 28	-1.05	+ 4	22.12	+1		
		12.2753	26.4207	- 56	0	+ .8	40 42 19.91	- 5	57.22	- 61	+ 10	-10	22.08	0		
		21.9867	18.6630	+ 8	- .2	+ .7	40 37 48.16	- 1	23.99	- 9	+ 6	- 3	24.11	0		
		24.2400	15.7913	0	+ .8	+1.8	40 32 49.01	+ 3	33.44	+ 47	+ 36	+ 7	23.35	0		
Dec. 27	V 7	D	17.2930	24.1723	+ 28	- .6	- .3	40 33 29.25	+ 2	53.86	+ 38	- 14	+ 5	23.40	-1	25.3
			13.4787	29.4697	+137	-1.3	+1.4	40 43 8.36	- 6	44.32	- 68	- 3	-12	23.21	-1	
			18.3983	24.8930	+ 63	+1.0	+1.3	40 33 38.81	+ 2	44.23	+ 37	+ 33	+ 5	23.79	-2	
			18.6083	23.8270	+ 37	+1.3	+1.2	40 38 35.04	- 2	11.94	- 18	+ 36	- 4	23.24	-2	
			32.3593 ^v	10.8103 ^u	+ 15	+1.7	+1.1	40 27 17.32	+ 9	4.43	+1.17	+ 42	+20	23.54	-2	25.1
	VI 1		27.1410	11.9863	- 40	+2.5	+ .5	40 42 46.18	- 6	22.73	- 63	+ 47	-13	23.16	+1	32.8
			21.3270	17.0340	- 24	-1.5	- .2	40 34 34.46	+ 1	48.39	+ 28	- 26	+ 4	22.91	+1	
			27.6547	13.5623	+ 52	+ .9	+1.0	40 42 20.06	- 5	56.13	- 61	+ 28	-10	23.50	0	
			18.0277	21.4313	- 7	+4.1	+1.5	40 37 48.30	- 1	25.97	- 9	+ 86	- 3	23.07	0	32.6
			15.8017	24.2570	0	+ .2	- .4	40 32 49.15	+ 3	33.60	+ 47	- 2	+ 7	23.27	0	
VI 2		24.3893	17.5337	+ 38	- .6	- .6	40 33 29.39	+ 2	53.29	+ 38	- 18	+ 5	22.93	-1		
		28.2307	12.2367	+ 23	- .6	0	40 43 8.49	- 6	44.10	- 68	- 10	-12	23.49	-1	32.4	
		22.4663	17.2300	- 5	- .9	- .5	40 38 35.16	- 2	12.26	- 18	- 21	- 4	22.47	-2	32.1	
		8.2587 ^u	29.8127 ^v	- 9	- .5	- .9	40 27 17.42	+ 9	4.48	+1.17	- 20	+20	23.07	-2	32.4	

The Constant of Aberration.

The present series appears to be much better adapted to an investigation of the aberration constant than that of 1889-90. The period covered is from October 10, 1892, to December 27, 1893—443 days. Hence if we assume, in accordance with Chandler's conclusion, that the latitude variation may be represented by two periodic terms of 12 and 14 months respectively, this series will embrace something more than the full term of 14 months. The investigation of this constant formed an important part of the original plan. To this end as many observations as possible were obtained in the morning and evening when the effect of aberration was near the maximum.

The distribution in Right Ascension of the 107 pairs of stars was as follows:

h	h		h	h		h	h		h	h	
0-1	4	Pairs.	6-7	4	Pairs.	12-13	5	Pairs.	18-19	5	Pairs.
1-2	4	"	7-8	6	"	13-14	3	"	19-20	5	"
2-3	4	"	8-9	5	"	14-15	5	"	20-21	5	"
3-4	4	"	9-10	4	"	15-16	5	"	21-22	4	"
4-5	5	"	10-11	4	"	16-17	4	"	22-23	5	"
5-6	5	"	11-12	4	"	17-18	4	"	23-24	4	"

There were in all 1780 observations before midnight and 1120 after midnight.

We may then write for each observation an equation of the form

$$\phi_0 + \Delta + \alpha x + \beta y + \gamma z + \delta u + \varepsilon v + \tau w = \phi,$$

where ϕ_0 is an assumed value of the latitude,

Δ a constant correction to ϕ_0 ,

$\alpha x + \beta y$ terms depending upon the 14 months period,

$\gamma z + \delta u$ terms depending upon the annual period,

εv correction required on account of erroneous aberration,

τw secular change in the latitude.

The longer period was assumed to be 430 days as indicated by the interval from maximum to maximum and minimum to minimum of this series in connection with that of 1889-90. The daily change of the argument is therefore $0^\circ.837$.

Let n be the number of days from January 1, 1893,

$$N = 0^\circ.837n,$$

\odot = the sun's true longitude,

Then

$$\begin{aligned} \alpha &= \cos N, & \beta &= \sin N, \\ \gamma &= \cos \odot, & \delta &= \sin \odot. \end{aligned}$$

Date			x	y	z	u	v	η	Observed ϕ
1892 December	2	1	+0.911	-0.411	-0.324	-0.946	+0.721	-0.076	3.18
	3	2	+ .918	- .397	- .307	- .952	+ .720	- .074	2.91
	5	3	+ .928	- .371	- .274	- .962	+ .717	- .068	3.00
	10	4	+ .953	- .302	- .189	- .982	+ .705	- .055	2.84
	12	5	+ .962	- .274	- .155	-0.988	+ .699	- .049	3.16
	20	6	+ .987	- .160	- .012	-1.000	+ .665	- .028	3.04
	23	7	+ .993	- .117	+ .042	-0.999	+ .650	- .019	3.13
	26	8	+ .997	- .073	+ .096	- .995	+ .632	- .011	3.12
	27	9	+0.998	-0.058	+0.113	-0.994	+0.625	-0.008	2.67
1893 July	19	10	-0.976	+0.218	-0.457	+0.889	-0.453	+0.551	3.75
	23	11	-0.987	+ .162	- .515	+ .857	- .414	+ .562	3.50
	August	2	-1.000	+ .016	- .649	+ .760	- .310	+ .589	2.85
		5	-1.000	- .028	- .687	+ .727	- .277	+ .597	3.02
	A.M.	6	-0.999	- .044	- .700	+ .714	- .266	+ .600	3.30
		7	- .998	- .058	- .711	+ .703	- .255	+ .603	2.89
		8	- .997	- .071	- .723	+ .691	- .244	+ .605	3.67
		9	- .996	- .087	- .735	+ .678	- .232	+ .608	3.25
		10	-0.995	-0.101	-0.747	+0.665	-0.220	+0.611	3.85
	1893 October	31	-0.269	-0.963	-0.783	-0.622	+0.641	+0.835	3.48
1893 November	6	20	- .182	- .983	- .712	- .705	+ .672	+ .852	3.65
	10	21	- .125	- .992	- .661	- .750	+ .689	+ .863	3.68
	11	22	- .110	- .994	- .648	- .762	+ .693	+ .865	3.72
	15	23	- .096	- .995	- .593	- .805	+ .705	+ .876	3.38
	16	24	- .038	- .999	- .579	- .815	+ .708	+ .879	3.39
	26	25	+ .108	- .994	- .427	- .904	+ .723	+ .906	3.18
	30	26	+ .167	- .986	- .362	- .932	+ .722	+ .918	3.57
	P.M.	4	+ .223	- .975	- .296	- .953	+ .719	+ .928	3.03
		6	+ .252	- .968	- .260	- .965	+ .715	+ .934	3.58
		7	+ .266	- .964	- .244	- .970	+ .713	+ .937	2.91
		10	+ .307	- .952	- .192	- .981	+ .706	+ .945	2.73
		13	+ .349	- .937	- .139	-0.990	+ .696	+ .953	3.18
		20	+ .443	- .896	- .016	-1.000	+ .667	+ .972	3.46
		24	+ .494	- .870	+ .054	-0.998	+ .645	+ .983	3.28
		25	+ .507	- .862	+ .071	- .997	+ .639	+ .986	2.67
		26	+0.520	-0.854	+0.091	-0.996	+0.633	+0.989	3.70
	December	4	+ .223	- .975	- .296	- .953	+ .719	+ .928	3.03
		6	+ .252	- .968	- .260	- .965	+ .715	+ .934	3.58
		7	+ .266	- .964	- .244	- .970	+ .713	+ .937	2.91
		10	+ .307	- .952	- .192	- .981	+ .706	+ .945	2.73
		13	+ .349	- .937	- .139	-0.990	+ .696	+ .953	3.18
		20	+ .443	- .896	- .016	-1.000	+ .667	+ .972	3.46
		24	+ .494	- .870	+ .054	-0.998	+ .645	+ .983	3.28
		25	+ .507	- .862	+ .071	- .997	+ .639	+ .986	2.67
		26	+0.520	-0.854	+0.091	-0.996	+0.633	+0.989	3.70

These are now combined by subtraction as follows:

now combined by subtraction as follows:								\sqrt{p}
10— 1	—1.887	+0.629	—0.133	+1.835	—1.174	+0.627	+0.57	0.64
11— 2	— .905	+ .559	— .208	+ .809	—1.134	+ .636	+ .59	.64
12— 3	— .928	+ .387	— .375	+ .722	—1.027	+ .657	— .15	.64
13— 4	— .953	+ .274	— .498	+ .709	—0.982	+ .652	+ .18	.64
14— 5	— .961	+ .230	— .545	+ .702	— .965	+ .649	+ .14	.64
15— 6	— .985	+ .102	— .699	+ .703	— .920	+ .631	— .15	.64
16— 7	— .990	+ .046	— .765	+ .690	— .894	+ .624	+ .54	.64
17— 8	— .993	— .014	— .831	+ .673	— .864	+ .619	+ .13	.64
18— 9	—1.993	—0.043	—0.860	+1.659	—0.845	+0.619	+1.18	0.64
19, 20—10	+0.751	—1.191	—0.290	—1.553	+1.109	+0.293	—0.19	0.72
21, 22—11	+ .870	—1.155	— .140	— .613	+1.105	+ .302	+ .20	.72
23, 24—12	+0.933	—1.013	+ .063	— .570	+1.016	+ .289	+ .53	.72
25, 26—13	+1.137	—0.962	+ .292	— .645	+0.999	+ .315	+ .36	.72
27, 28—14	+ .236	— .927	+ .423	— .674	+ .983	+ .331	— .00	.72
29, 30—15	+ .284	— .900	+ .493	— .679	+ .966	+ .337	— .07	.72
31, 32—16	+ .393	— .845	+ .645	— .686	+ .925	+ .357	— .85	.72
33, 34—17	+ .496	— .779	+ .797	— .675	+ .874	+ .376	— .27	.72
35—18	+1.515	—0.753	+0.838	—1.661	+0.853	+0.378	— .15	0.64

The following system was adopted in the assignment of weights.

Each evening or morning equation was given the weight unity where the difference of zenith distance was less than 15 revolutions of the screw (12'.6).

In case of pairs whose difference of zenith distance was 15 or more revolutions the weight $\frac{1}{2}$ was assigned.

As appears from the example, one morning observation may be combined with the mean of two or more evening observations or *vice versa*. Also the same morning or evening observation may enter into more than one combination; thus the morning series above is combined with each of the two evening series.

p_1 and p_2 being the weights of the two equations, that of the difference equation is

$$\frac{p_1 p_2}{p_1 + p_2}.$$

When the same observation equation enters into two combinations it is given in each the weight $0.7p$.

When two equations are combined into a single mean it is given weight $2p$.

When three or more equations are so combined the weight is $3p$.

In this manner were formed 1219 difference equations. When these resulted from observations made within an interval of a few days, their coefficients were so nearly equal that frequently it was advantageous to combine several difference equations into one. This was done by the simple process of addition, as shown by the following example:

$$\begin{array}{r} -1.09x + 1.65y + 1.15z + 1.35u - 1.42v' + 0.65w = + 0.27 \quad \sqrt{p} = 0.64 \\ -1.17 + 1.60 + 1.10 + 1.43 - 1.40 + 0.64 - 0.19 \quad 0.64 \\ -1.20 + 1.58 + 1.06 + 1.46 - 1.39 + 0.63 + 0.32 \quad 0.64 \\ -1.05 + 1.66 + 1.16 + 1.30 - 1.26 + 0.66 + 0.15 \quad 0.76 \\ -1.11 + 1.63 + 1.12 + 1.35 - 1.25 + 0.65 + 0.34 \quad 0.64 \\ \hline \Sigma \quad -5.62x + 8.12y + 5.59z + 6.89u - 6.72v' + 3.23w = + 0.89 \quad \sqrt{p} = 0.305 \\ -1.71x + 2.48y + 1.70z + 2.10u - 2.05v' + 0.99w = + 0.27 \end{array}$$

The final equation is the summation equation multiplied by the square root of its weight. The latter is derived as follows:

Let $p_1 \cdot p_2 \dots p_n$ be the weights of the individual equations, the weight of the sum is

$$\frac{(p_1 \cdot p_2 \dots p_n)}{(p_2 \cdot p_3 \dots p_n) + (p_1 \cdot p_3 \dots p_n) + \dots + (p_1 \dots p_{n-1} \cdot p_n)}.$$

By tabulating the terms of this formula for the values of p which actually occurred the weights were readily computed.

By this process of combining, the number of equations was reduced to 190. These were then combined in the usual manner to form the six normal equations which follow:

$$\begin{array}{l} 697.1376x - 82.5669y + 239.3309z - 619.6463u + 74.3262v' - 198.3408w = - 32.0961 \\ + 664.8606y + 544.5932z + 408.5788u - 99.2513v' - 34.9435w = - 76.1616 \\ + 639.9110z + 53.0980u - 32.9367v' - 63.8902w = - 84.4461 \\ + 757.0544u - 112.3893v' + 107.7806w = - 12.3723 \\ + 426.7316v' + 1.4786w = - 35.2360 \\ + 126.1514w = + 13.5975 \end{array}$$

From which

$$\begin{aligned}x &= -.1119 \pm .1255 \\y &= -.1090 \pm .0587 \\z &= -.0029 \pm .0723 \\u &= -.0572 \pm .0642 \\v' &= -.1036 \pm .0092 \\w &= -.0497 \pm .0919\end{aligned}$$

The probable error of a single equation of weight unity is $\pm 0''.182$.

It was obvious from the beginning that the 12 and 14 months terms could not be separated with any certainty in a series of this character, but it was thought best to include both for the sake of completeness. The indetermination is shown very conspicuously by the large probable errors of x , y , z and u . This however does not extend to v' , the probable error of which is quite small.

Remembering the significance of v' we have for the correction to Struve's value of the aberration constant

$$\begin{array}{rcl}\frac{20.4451}{20} v' & = & .1059 \\ \text{Struve's value} & & 20.4451 \\ \text{Resulting value of constant} & & \mathbf{20''.551 \pm 0094}\end{array}$$

A second solution of the normal equations, excluding the terms depending on the annual period, gives

$$\begin{aligned}x &= -.0563 \pm .0097 \\y &= -.1381 \pm .0074 \\v' &= -.1048 \pm .0090 \\w &= -.0177 \pm .0227 \\ \text{Correction to Struve's constant} &= + .1071 \\ \text{Value of constant} & \mathbf{20''.552 \pm 0092}\end{aligned}$$

Finally, if we exclude from our equations every unknown quantity except v' we find

$$\begin{aligned}\text{Correction} &= .0844 \\ \text{Constant} & \mathbf{20''.530}\end{aligned}$$

If the latitude variation can be represented by a single periodic term, and the observations were distributed uniformly throughout a full period, both with respect to the right ascensions of the stars employed and the date of observations, we should expect the last two values to be practically equal.

The value $20''.551$ is that adopted in the reduction of the present series. The necessary correction to the latitude is found by multiplying the computed reduction for aberration by the factor .00518. This correction is applied to the individual values of the latitude before beginning the process of adjustment which follows.

In what follows, the differences of the consecutive values of the latitude are given with the weight given by the expression

$$p = \frac{nn'}{10(n+n')}$$

When two or more differences are combined the value of p given is the sum of the individual weights. The primed values of I–II, etc., refer to the morning series.

	p	$1-p$		p	$1-p$		p	$1-p$		p	$1-p$
I- II + .129	2.87	.3484	I- II' + .166	3.38	.2959	I- II'' + .110	4.33	.2309	III- VII - .099	2.55	.3922
II- III - .232	2.42	.4132	II- III' - .338	1.53	.6536	I- III' - .182	2.76	.3623	III- IX + .514	1.02	.9804
III- IV + .028	2.14	.4673				I- IV + .013	3.22	.3106	III- X + .203	1.65	.6061
IV- V + .029	3.05	.3279	IV- V' + .082	1.36	.7353	I- V' + .024	5.45	.1835	III- XI + .130	4.12	.2427
V- VI - .055	2.78	.3597	V- VI' - .144	2.66	.3759	I- VI + .067	3.83	.2611	IV- VIII + .164	2.45	.4082
VI- VII + .067	3.00	.3333	VI- VII' + .091	1.51	.6623	I- VII' - .130	0.61	1.6393	IV- X - .000	1.53	.6536
VII- VIII - .021	1.58	.6329	VII- VIII' + .256	1.73	.5780	I- VIII + .083	2.06	.4854	V- VI'' + .006	2.19	.4566
VIII- IX + .013	2.49	.4016	VIII- IX' + .322	1.09	.9174	II- III'' - .236	4.77	.2096	V- IX + .119	2.17	.4608
IX- X - .155	2.55	.3922	IX- X' - .098	2.21	.4525	II- V + .161	1.55	.6452	V- X - .018	3.72	.2688
X- XI - .046	3.96	.2525	X- XI' + .016	1.44	.6944	II- V' - .057	4.31	.2320	V- XI - .196	1.27	.7874
XI- I + .076	8.88	.1126				II- VI - .144	4.45	.2247	VI- IX + .072	1.03	.9709
						II- VIII - .137	1.49	.6711	VI- XI + .092	1.75	.5714
						II- IX + .008	1.44	.6944	VII- X + .009	2.20	.4545
						III- V - .053	3.03	.3300	VIII- XI - .104	2.93	.3413
						III- VI + .029	7.22	.1385	IX- XI - .254	1.76	.5682

Representing by 1.2, 2.3 1.2', 2.3' the required corrections to I–II, II–III, the conditions to be satisfied are expressed by the 29 equations following:

<i>I. p.</i>	3484	4132	4673	3279	3597	3333	6329	4016	3922	2525	1126	2959	2309	6536	2096	7353	3759	4566	6623	5780	9174	4525	6944	6452	2611
1	+	+	+	+	+	+	+	+	+	+	+	— /													
2	1.2	2.3										1.2													
3	+												— /												
4		2.3											— /												
5		2.3											— /												
6				4.5																					
7					5.6																				
8					5.6																				
9						6.7																			
10							7.8																		
11								8.9																	
12									9.10																
13										10.11															
14	1.2																5.6							2.5	6.1
15		2.3																							
16			3.4																						
17				4.5																					
18					5.6																				
19						6.7																			
20							7.8																		
21								8.9																	
22									9.10	10.11	11.1	+	1.2												
23										10.11	11.1	+	1.2		2.3										
24											11.1	+													
25											11.1	+					4.5								
26													1.2												
27																								2.5	
28															2.3										
29																		5.6							

Employing the usual method of solution by correlates we derive the following system

	k_1	k_2	k_3	k_4	k_5	k_6	k_7	k_8	k_9	k_{10}	k_{11}	k_{12}	k_{13}	k_{14}	k_{15}
1	.4016														
2	.3484	.3484	.3484	.4132	.4132	.3279	.3597	.3597	.3333	.6329	.4016	.3922	.2525	.3484	.4132
3	.3484	.3484	.5793											.3484	
4	.4132			1.0668	.4132									.3484	.4132
5	.4132			.4132	.6228										.4132
6	.3279					1.0632									
7	.3597						.7356	.3597						— .3759	
8	.3597						.3597	.8163							
9	.3333								.9956						
10	.6329									1.2109					— .5780
11	.4016										1.3190				
12	.3922											.8447			
13	.2525												.9469		
14	.3484	.3484	.3484				— .3759							1.6306	
15	.4132			.4132	.4132					— .5780					2.0545
16	.4673										— .9174				
17	.3279					.3279						— .4525			
18	.3597						.3597	.3597				— .4525			
19	.3333								.3333				— .6944		
20	.7455									.6329					
21	.5142										.4016				
22	.7573	— .2959										.3922	.2525		
23	.3651	— .2959		— .6536									.2525		
24	.1126														
25	.1126					— .7353									
26		— .2309													
27														.6452	
28					— .2096										
29								— .4566							

The solution of these equations gives for k_1, k_2 — —, and finally 1.2, 2.3, . . . the

$k_1 = +.1785$	$k_{11} = -.4001$	$k_{21} = -.0049$	$v, 1. 2 = .3484 (k_1 + k_2)$
$k_2 = -.1797$	$k_{12} = -.1621$	$k_{22} = -.0485$	2. 3 = .4132 ($k_1 + k_4$)
$k_3 = +.1912$	$k_{13} = -.1898$	$k_{23} = +.1050$	3. 4 = .4673 ($k_1 + k_{16}$)
$k_4 = +.2553$	$k_{14} = -.0955$	$k_{24} = +.0163$	4. 5 = .3279 ($k_1 + k_6$)
$k_5 = -.3257$	$k_{15} = -.0894$	$k_{25} = -.0880$	5. 6 = .3597 ($k_1 + k_7$)
$k_6 = -.1661$	$k_{16} = -.1624$	$k_{26} = +.1782$	6. 7 = .3333 ($k_1 + k_9$)
$k_7 = +.2128$	$k_{17} = +.0010$	$k_{27} = +.3659$	7. 8 = .6329 ($k_1 + k_{10}$)
$k_8 = -.4010$	$k_{18} = -.0650$	$k_{28} = -.3081$	8. 9 = .4016 ($k_1 + k_{11}$)
$k_9 = -.0557$	$k_{19} = -.0841$	$k_{29} = -.3262$	9.10 = .3922 ($k_1 + k_{12}$)
$k_{10} = -.3475$	$k_{20} = -.0330$		10.11 = .2525 ($k_1 + k_{13}$)
			11. 1 = .1126 ($k_1 + k_{20} + k_{21}$)

k_{16}	k_{17}	k_{18}	k_{19}	k_{20}	k_{21}	k_{22}	k_{23}	k_{24}	k_{25}	k_{26}	k_{27}	k_{28}	k_{29}	
.4673	.3279	.3597	.3333	.7465	.5142	.7573 — .2959	.3651 — .2959	.1126	.1126					— .167 — .037 + .019 + .106 + .004
	.3279	.3597 .3597	.3333	.6329			— .6536		— .7353	— .2309		— .2096		— .053 + .089 — .061 — .024 — .277
— .9174	— .4525	— .4525	— .6944		.4016	.3922 .2525	.2525							— .309 — .057 — .062 + .079 + .062
2.7733	1.8948 .4525	.4525 2.0519	2.0536	2.7261	.1126	.1126	.1126	.1126	.1126		.6452			— .000 + .050 — .063 — .000 — .179
				.1126	1.5678	.1126	.1126	.1126	.1126					— .082 + .049 + .061 + .024 — .025
				.1126	.1126	1.7476	.6610	.1126	.1126					
				.1126	.1126	.6610	1.9207	.1126	.1126					
				.1126	.1126	.1126	.1126	.7176	.1126					
				.1126	.1126	.1126	.1126	.1126	1.9459					
										.6464 — .2320	— .2320 .8772			+ .029 + .218 — .063 — .076
												.5728 — .1385	— .1385 .9267	

values following:

$+k_2 + k_{14}$	$= +.033$	$v, 1. 2' = .2959 (-k_2 + k_{22} + k_{23}) = +.070$
$+k_5 + k_{15}$	$= +.008$	$1. 2'' = .2309 (-k_3 + k_{26}) = -.003$
	$= +.008$	$2. 3' = .6536 (-k_4 + k_{23}) = -.098$
$+k_{17}$	$= +.004$	$2. 3'' = .2096 (-k_5 + k_{28}) = +.004$
$+k_8 + k_{18}$	$= -.027$	$4. 5' = .7353 (-k_6 + k_{25}) = +.057$
$+k_{19}$	$= +.013$	$5. 6' = .3759 (-k_7 + k_{14}) = -.116$
$+k_{20}$	$= -.128$	$5. 6'' = .4566 (-k_8 + k_{29}) = +.034$
$+k_{21}$	$= -.091$	$6. 7' = .6623 (-k_9) = +.037$
$+k_{22}$	$= -.013$	$7. 8' = .5780 (-k_{10} + k_{15}) = +.149$
$+k_{22} + k_{23}$	$= +.011$	$8. 9' = .9174 (-k_{11} + k_{16}) = +.218$
$+k_{22} + k_{23} + k_{24} + k_{26}$	$= +.014$	$9.10' = .4525 (-k_{12} + k_{17} + k_{18}) = +.044$
		$10.11' = .6944 (-k_{13} + k_{19}) = +.073$

Applying these corrections to the differences of consecutive groups given on page 389 we obtain the corrected differences, viz. :

I- II + .096	Therefore we have
II- III — .240	I = II + .096
III- IV + .020	III — .144
IV- V + .025	IV — .124
V- VI — .028	V — .099
VI- VII + .054	VI — .127
VII-VIII + .107	VII — .073
VIII- IX + .104	VIII + .034
IX- X — .142	IX + .138
X- XI — .057	X — .004
XI- I + .062	XI — .061
Σ + .001	

Adding .033 to each group in order to make the algebraic sum of these corrections zero, we find the following series of values which are applied to the results from the different groups to reduce all to a homogeneous system :

I + .033	VII — .040
II + .129	VIII + .067
III — .111	IX + .171
IV — .091	X + .029
V — .066	XI — .028
VI — .094	

Final Values of the Latitude.

In the final results which follow, all known corrections and reductions have been applied. The tabular statements seem to require no further explanation. The folding sheet gives the individual results as derived from each observation. The probable error of a single determination, derived from these values and therefore including the outstanding error of the adjusted declinations, is as follows :

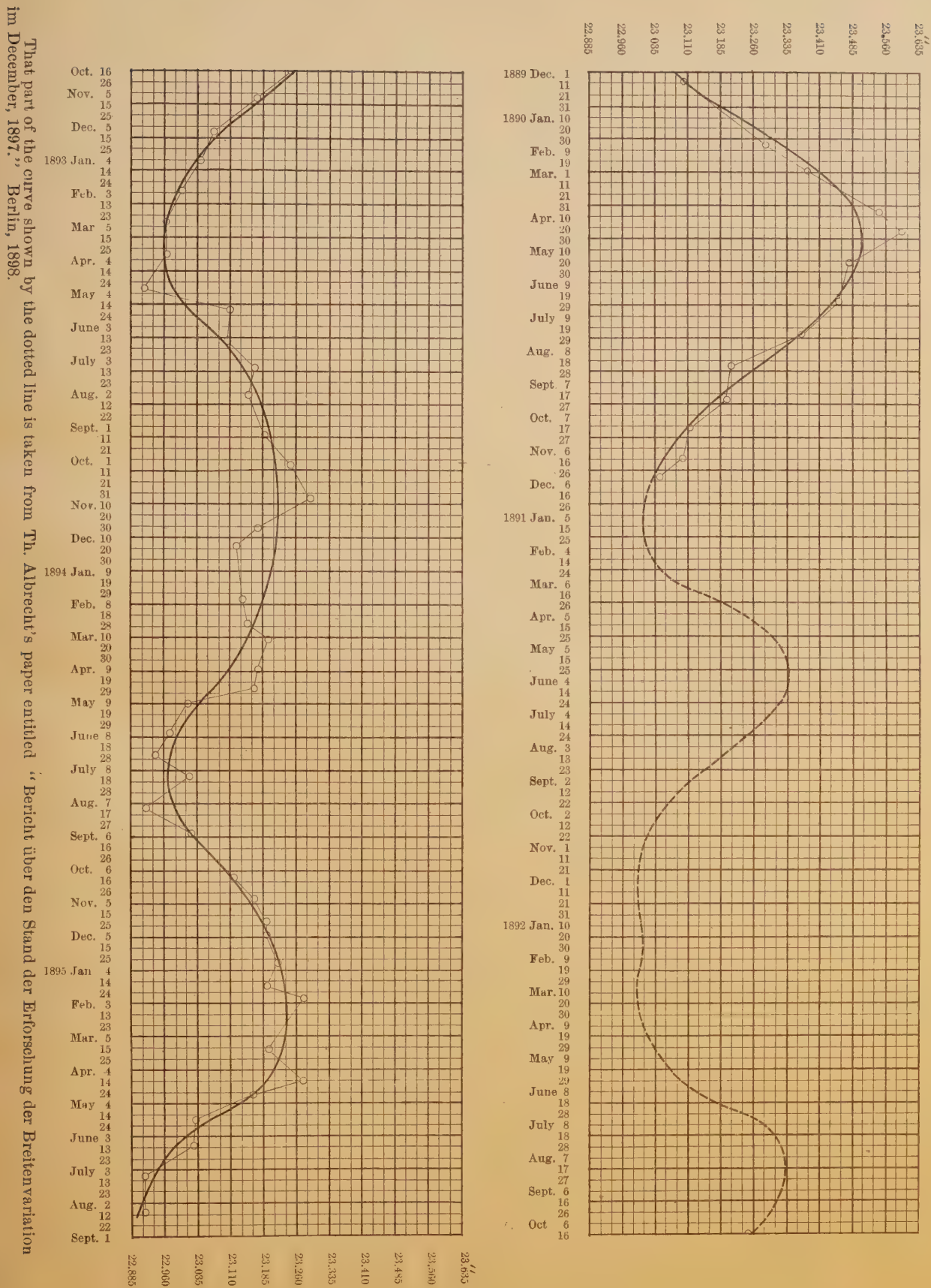
Group	I	0.209	393	Observations.
	II	.200	343	"
	III	.206	382	"
	IV	.227	172	"
	V	.263	299	"
	VI	.239	359	"
	VII	.194	151	"
	VIII	.194	181	"
	IX	.238	139	"
	X	.207	248	"
	XI	.196	223	"
<hr/>				
Mean,		0.216	2890	"

Daily Mean of Latitude.

		P.M.	No.	A.M.	No.			P.M.	No.	A.M.	No.			P.M.	No.	A.M.	No.	
1892 October	10	3.45	5	3.10	11	1893 March	6	2.92	17	''		1893 August	8	3.23	18	3.11	10	
	11	3.38	12	3.03	9		7	2.90	17	2.87	4		9	3.09	18	3.18	10	
	14	3.28	12	3.18	13		13	3.10	14	3.39	6		10			3.05	10	
	16			3.17	18		16	3.02	7				2	3.32	18	3.04	9	
	19	3.37	12	2.93	19		17			3.11	10		3	3.33	16	3.27	5	
	21	3.53	12	3.20	19		18	2.83	21	3.15	9		6	3.27	18			
	23	3.46	10	2.96	6		21	3.10	5				8	3.21	17	3.09	10	
	24	3.29	5				27	2.98	20	2.88	7		9	3.23	17			
	30	3.13	14	2.94	16		28	2.80	20	2.88	5		12	3.22	14			
	November	5	3.23	8				29	3.11	21	3.04		7	16	3.33	12		
		8	3.22	12				2	2.92	17				17			3.12	7
		11	3.55	12				4	3.07	6	2.62		9	19			2.97	7
13		3.27	15	3.27	12	16	3.12	11			20			3.22	17			
16				3.08	13	17			3.10	11	21			3.06	12			
December	17	3.02	12			18			3.09	10	23			3.08	17			
	20			3.60	4	23			3.07	6	27	3.31	16					
	22			2.97	11	24	2.86	19			29	3.34	14					
	26			3.13	13	25	3.03	2	2.66	9	30	3.15	18	3.29	10			
	1	2.99	13			28	2.88	17			1	3.46	18	3.33	10			
	2	3.19	14			6	2.96	15	2.84	10	2	3.21	18	3.31	10			
	3	2.91	15			7	3.07	15	3.06	10	3			3.33	10			
	5	2.93	16	3.36	13	8	2.88	15			7	3.34	11					
	9			3.50	8	9	2.95	16			8			2.96	10			
	10	3.04	15			10	3.14	18			9			3.08	10			
	11			3.15	13	11			3.16	11	14	3.30	17	3.00	10			
	12	3.13	14			12	3.01	15			17	3.47	18					
1893 January	15			3.19	3	19	3.14	16	2.98	11	18	3.23	17					
	17			2.96	16	31	3.24	12			20	3.44	6					
	18			2.94	11	7	3.16	11	3.32	12	21	3.35	5					
	20	2.81	12			8	3.06	17	3.11	11	24	3.28	18					
	22			2.88	2	9	3.05	17	3.17	13	25			2.91	12			
	23	3.04	8			11	3.01	13	3.10	2	28			3.49	10			
	25			3.17	8	13	3.08	17			29			3.10	12			
	26	2.85	17			14			3.03	10	30			3.50	12			
	27	3.14	14	3.07	12	17			3.19	14	31	3.35	18	3.19	11			
	28	2.93	18	2.92	9	20	3.16	14			3	3.23	9					
	3			2.95	10	23	3.17	15	3.02	8	6	3.38	19	3.33	11			
	7			3.03	5	24	3.13	14			10	3.36	19	3.37	12			
February	13	3.21	13			28			3.25	14	11	3.36	19	3.36	12			
	16	3.09	12			30			2.99	14	15	3.27	18	3.02	12			
	17	3.16	13			2	3.15	18	3.62	1	16	3.37	19					
	19			3.01	11	5			3.24	12	26	3.20	19					
	20			2.77	8	7	3.05	9			29	2.87	1					
	21	2.78	20			9	3.26	18	3.12	14	30	3.24	17					
	23	3.14	9			10	3.20	18	3.18	12	4	3.24	18	3.25	5			
	25	2.93	20			11	2.98	12			5			3.05	10			
	26	3.09	19			16	3.24	9			6	3.27	16					
	3			2.92	10	17	3.26	10	3.15	13	7	3.27	10	3.42	9			
	4	2.71	18	3.21	10	18	3.09	9	3.06	11	10	3.14	10	3.15	10			
	8	3.17	15			19	3.05	10	3.19	14	12	2.80	10					
March	11			3.12	12	20	3.23	15	3.44	1	13	3.16	10	3.56	9			
	14	2.98	14			23			3.17	16	17	3.34	1					
	15	2.85	8	3.13	11	27	3.08	18			20	3.26	10	3.22	10			
	16			2.92	10	29	3.11	18			23	2.70	9					
	20	2.76	22			30	3.22	17			24	3.12	10	3.04	10			
	24	2.78	5			2			3.23	8	25	2.79	10	3.15	7			
	25			2.90	12	5	3.06	16	3.26	9	26	3.23	10	3.05	10			
	26	2.94	21	3.08	11	6			3.21	10	27			3.00	9			
	1	2.82	15	2.87	10	7	3.07	2	3.18	10								
	521					379	653					364	606					377

<i>Weighted Mean Date</i>			<i>ø P.M.</i>	<i>No.</i>	<i>ø A.M.</i>	<i>No.</i>	<i>Mean</i>	<i>A.M.-P.M.</i>
1892	October	17	3.397	18	3.095	95	3.246	— .302
	November	12	3.234	73	3.106	69	3.170	— .128
	December	10	3.004	107	3.147	66	3.076	+ .143
1893	January	5	3.048	87	2.991	63	3.020	— .057
	February	8	2.944	123	3.065	53	3.004	+ .121
	March	3	2.900	118	3.025	53	2.962	+ .125
	March	31	2.958	121	2.977	58	2.968	+ .019
	May	1	2.938	68	2.895	35	2.916	— .043
	May	18	3.066	103	3.155	34	3.110	+ .089
	June	17	3.093	107	3.115	86	3.104	+ .022
	July	13	3.162	128	3.170	94	3.166	+ .008
	August	4	3.131	107	3.172	67	3.152	+ .041
	September	11	3.271	112	3.107	84	3.189	— .164
	October	7	3.315	176	3.185	70	3.250	— .130
	November	6	3.343	121	3.247	104	3.295	— .096
	December	2	3.232	71	3.117	15	3.174	— .115
	December	18	3.059	90	3.194	74	3.126	+ .135
			1780		1120			

Diagram Showing the Variations of Latitude at the Sayre Observatory, South Bethlehem, from December 11, 1889, to August 12, 1895.



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